RECONSTRUCTIVE SURGERY OF THE UPPER EXTREMITY

ARTHUR STEINDLER

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SURGICAL MONOGRAPHS

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TO

DR. JOHN RIDLON OF CHICAGO

THE TEACHER

THE ADVISER

THE FRIEND

PREFACE

This book is written as a record of personal experience rather than as a textbook on the orthopedic surgery of the upper extremity. The fact that it is a monograph on a definite subject will serve as an explanation for the rather perfunctory treatment which has been given some of the chapters. This is especially true of those pertaining to tuberculosis and chronic arthritis.

Subjects of general orthopedic nature, such as heliotherapy, and so on, are only referred to shortly as the occasion arises, and should be looked up in a general textbook of orthopedic surgery.

It is hoped that the keen interest in the orthopedic ailments of the arm and hand which prompted the writing of this book will find response, and that it will be a factor in stimulating contributions of more exhaustive and more valuable nature covering the many problems and questions of this field of surgery.

Acknowledgment and appreciation are due to Miss M. Prosser, in charge of the muscle educational work, for her valuable aid given in the writing of the chapter on physiotherapy; to Dr. R. V. Funsten for his help in arranging photographs and records; and to Dr. F. L. Knowles for most of the drawings.

A. Steindler

Iowa City, Iowa.

INTRODUCTION

Orthopedic surgeons are finding it hard to define the scope of their specialty. No designation has been found which is at the same time sufficiently limiting and sufficiently inclusive. It is becoming more and more the functional surgery of the extremities and the spinal column.

Much has been written on the surgery of the spine. The corrective surgery of the lower extremity has also received much attention. The surgery of the shoulder girdle, arm and hand has been less thoroughly considered and there is great need for such consideration.

It is natural that improved locomotion and weight bearing have seemed the first requisites. Rarely, however, can locomotion be so bettered as to compete with the normal, and often this improvement adds little to wage-earning capacity. We would do well to consider the material increase in this capacity which even slight improvement in the function of the upper extremity makes possible.

This deserved consideration has been given in this book by Professor Steindler.

I shall never forget the stimulation which I received from a visit to Dr. Steindler's clinic at the University of Iowa. I had expected much, for I had appreciated the careful work which the author's many previous contributions to orthopedic surgery have evidenced. But I had hardly expected to find such ideal conditions for the standardization of methods of procedure for the betterment of the cripple. An enthusiastic, thoughtful, and skillful chief of clinic, excellent hospital facilities, few distracting social obligations or scattered private patients and an enlightened state government providing sufficient support and assuring beneficent control of cases, to make "follow up" and real end-result studies possible.

The book proves that good use of these facilities has been made. One cannot escape the impression that the principles herein advocated must be sound. If any exception can be taken to the style, it is that scarcely an unnecessary word has been employed. There is no "padding." Each sentence must be read with attention. No cursory skimming of the well-illustrated pages will make one master of the knowledge which they contain. They are largely reports of personal experience, not reviews of other men's work.

Especially valuable and commendable are the descriptions of the muscle dynamics of the shoulder, and the careful anatomical review of the action and relative importance of the muscles controlling the finer movements of the hand. The bearing which these considerations have on tendon transplantation is of supreme importance.

There are excellent sections on physiotherapy, muscle re-education, and substitutionary movements. The simple apparatus and methods of recording progress are most practical.

It is a book which every one who contemplates performing operations for the restoration of function in the upper extremity should read and, usually, should follow. Its frank report of personal work, by no means always successful, gives a judicial tone which medical books too often lack. No attempt is made to prove a preconceived theory, but many original methods are described; methods which demand a trial because of their rationality and the convincingly successful results which the author has obtained.

This is the type of book we need; unspectacular, straightforward, the conclusions of a thoughtful man who believes his experience in a limited field has taught him certain things which it is his duty to pass on to his colaborers in the art of healing.

Robert B. Osgood

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CHAPTER I

SUBACROMIAL BURSITIS

SYNONYMS.—Subdeltoid bursitis; periarthritis humeroscapularis (Duplay); luxation de la longue portion du muscle biceps huméral (Jarjavey).

Anatomy.—The subacromial bursa extends from the upper third of the deltoid muscle to the under surface of the acromion process. It separates the greater tuberosity from the deltoid muscle, the acromion process and the coraco-acromial ligament. By plaster-of-Paris injections of the bursa, T. T. Thomas found that, in most cases, the bursa itself is circumscribed to the greater tuberosity and to the region of the supraspinatus and infraspinatus tendons. Only a small portion, about half an inch, extends under the acromion. In outward rotation, the subdeltoid portion is much smaller than in inward rotation. The sac does not communicate with the shoulder joint. Kuester, from dissections or observations on one thousand shoulder joints, reports only two instances of communication between the bursa and the joint. Due to its situation, any effusion in the bursa is bound to cause a prominence of the deltoid muscle, and an outlet for the fluid contained would most likely be situated at the anterior edge of this muscle. It is here where effusions can be reached most conveniently.

The main function of this bursa consists in its mechanism as a gliding apparatus, which is indispensable for the abduction and rotation movement of the humerus. In abduction, it disappears under the acromion; and in adduction, it assumes a position under the deltoid muscle. In the rotatory motion of the humerus, it also constantly changes its configuration, acting then as gliding apparatus placed between the deltoid and the rotators attached to the upper end of the humerus. The outlines of the bursa are therefore constantly changing and its walls forever gliding over each other during the act of motion in the shoulder joint.

Synovial fluid secreted by the endothelial lining of the wall takes care of free and easy motion between the walls. The bursa cannot be dissected out as a whole because its walls are very closely connected with, and adherent to, the under side of the acromion.

Pathology.—The bursa is subject to the same inflammatory changes as any other bursa in the body. In acute inflammation of the bursa, a serous, hemorrhagic, or purulent exudate accumulates in the bursa, making aspiration, or sometimes incision, necessary. The chronic inflammations of the bursa are of greatest orthopedic interest, as they may lead to severe chronic disabilities of the shoulder. In the different stages of development of chronic bursitis, we observe hyperemia of the wall, thickening, and the formation of adhesive strands, which finally may obliterate the bursa entirely. Sometimes, villous enlargements will be found in the interior of the bursa (Painter), or nictitating folds such as seen in other synovial cavities. They, as well as the thickened wall, are often responsible for the impairment of the free gliding mechanism which is the chief function of this bursa. To these changes are to be added the aggregation of lime salts sometimes found in the form of granules within the bursal wall. These granules are partly surrounded by giant cells, and partly directly overlie the epithelioid cells of the wall (Painter).

The earlier writers concentrated their entire attention upon the bursa itself as the seat of the disease. It is only since the observations of Codman and others that attention has been paid to neighboring structures such as the floor of the bursa and the adjacent tendons. The most important of these tendons is that of the supraspinatus muscle. Coming from the supraspinous fossa of the scapula, it finds its insertion at the uppermost facet of the greater tuberosity of the humerus. It assists the deltoid muscle in abduction, acting upon the humerus as a lever of the first order; and it has also a backward extending action upon the humerus. The tendon of this muscle is closely aligned with the floor of the subdeltoid bursa. Codman found that tears occur in the supraspinatus tendon which are followed by hemorrhage, the extravasation of blood, and, finally, the formation of a scar in the tendon. In addition to this, Wrede found that necrobiotic changes take place in the tendon tissue following these tears, with the result that irregular bodies of lime salts are deposited in the tendon. In the recognition of the extrabursal location of these lime deposits, a decided step forward has been made in our knowledge of the pathology of this disease. Brickner devoted very extensive studies to this condition, calling attention to "certain prevailing fallacies as regards our conception of subacromial bursitis." He also finds the calcareous deposits beneath the bursa imbedded in the supraspinatus or infraspinatus tendons, following small tears of these tendons which lead to necrobiotic changes of the tendon tissue.

One must, therefore, in the pathology of subacromial bursitis, consider first actual bursitis with thickened walls, adhesions, and a nondescript content of detritus. These cases give no X-ray evidence, nor do those bursae which contain scar tissue, adhesions, or fluid.

Then there are definite calcareous deposits now considered to be largely sub-bursal, and situated in the supraspinatus tendons. These cases do give X-ray evidence. They show a distinct shadow overlying

the head of the humerus, in outlines distinct from it and without definite bone structure. The lime deposits are found in sandlike particles or in larger plaques, and sometimes they have penetrated the tendon diffusely. They consist of calcium carbonates and oxalates. This depositing of lime salts into necrotic tendon tissue following a tear of the tendon is not a unique feature. We find the same condition in the triceps, brachialis anticus, and especially in the adductors of the femur and in the extensor quadriceps muscle. In all these instances, the deposits follow traumatism and tears in the tendons.

The onset of subacromial bursitis is often acute following a distinct trauma. Common among the causes is sudden sprain of the shoulder from forced abduction. In other instances the onset is insidious and the traumatism of a more chronic or occupational nature. Stretching the arm above the head, strap hanging, or other instances of mild traumatism have been mentioned as inducing or causing subdeltoid bursitis.

Symptoms.—The most important symptom is pain. It is the most prominent as well as the most persistent feature. There is, first of all, a local tenderness to pressure over the deltoid muscle, usually situated over the middle portion or in front of it directly below the acromion process.

Pain in the shoulder becomes most marked, however, when motion is carried out in certain directions, namely, those of abduction and outward rotation. When the arm is abducted, the pressure point under the acromion often disappears (Dawburn's sign). This can be explained by the fact that in abduction the bursa disappears partly under the acromion and, therefore, is not so accessible to palpation.

It is often possible to abduct the patient's arm to the horizontal without pain; but when attempting to hold the arm in this abducted position, the patient complains (Codman).

Radiation of pain is very common. It follows most often the distribution of the internal cutaneous nerve, also that of the external cutaneous nerve. In some cases that came within my observation, manipulation of the arm was followed by distinct pain in the elbow joint, though no motion of that joint had been undertaken. The patients are usually very uncomfortable at night, finding it impossible to assume a proper posture, and sleeping upon the affected side is usually out of the question. They often speak of peculiar nocturnal attacks and exacerbations of pain.

It has already been stated that motion of the shoulder joint is very much restricted. Active abduction is almost totally lost. Outward rotation is nearly impossible. Passive abduction of the arm is possible only to a limited extent. Beyond this it is soon stopped by pain, and the automatic contracture of the adductor muscles will stop further motion. Still, in this partial loss of motion, we find a point of great importance for the differential diagnosis between subdeltoid bursitis and affections of the shoulder joint itself.

If an effusion exists in the shoulder joint, or in any other form of arthritis, the shoulder joint will, as Lange has pointed out, assume a

pathognomonic position. This position is slight abduction of about 25° or 30°, and slight forward flexion, similar to what we observe in the hip joint, if the latter is affected. If the arm is allowed to fall to the side of the body, in cases of arthritis, this position is only apparently one of complete adduction. The arm is still in actual abduction of 25°, and the apparent adduction is carried out by rotation of the scapula over the sternoclavicular joint. This fact becomes evident by the obliquity of the vertebral border of the scapula when the patient is seen from behind. As soon as the scapula is righted so as to maintain a position symmetrical to the other side, the true position of the shoulder joint is established.

Subacromial Bursitis

In subacromial bursitis, the condition is entirely different. Very slight motion is possible in all directions passively, but the further ranges of abduction and inward rotation are inhibited by pain and muscle contractures. This we believe is a very useful point in differential diagnosis, and more attention should be paid to the true position of the shoulder-blade when a distinction between extra-articular and intra-articular pathologic changes is to be made.

It can readily be seen that, under these circumstances, the patients find themselves in a state of considerable helplessness. The hand cannot be carried easily above the waistline, nor back of the frontal plane, and only very small circumductory motions are possible in the shoulder. The patient is unable to dress himself or to carry out the most common activities of life.

A great deal of discussion has arisen about the interpretation of X-ray findings. As already stated, synovitis of the bursa itself, with thickening of the walls and adhesions, gives no X-ray evidence, while cases of lime deposits in the supraspinatus tendon give distinct X-ray findings. On the other hand, X-ray shadows may be present without any symptoms whatsoever (Frauenthal).

Brickner also reported transitory shadows, disappearing in intervals of from 25 days to 14 months. In 4 of Painter's cases, shadows were present, and of 100 cases reported by Brickner, 19 showed shadows, and, on operation, also calcareous deposits.[1]

[1] Osgood states that he is impressed with the frequent disappearance of lime salts in the tendon without operation (personal communication).

Differential Diagnosis.—There are a number of conditions which produce symptoms similar to those of subdeltoid bursitis. While there is no great difficulty in determining lesions of the humerus itself, such as fracture of the greater tuberosity, the scapula, the acromion, or the outer portion of the clavicle, it is quite different with the lesions concerning the soft structures surrounding the shoulder joint. Various sprains and tears may occur in the neighborhood of the humeral head; similar to the tears found in the supraspinatus tendon, there occur also those of the tendons of the latissimus dorsi and pectoralis major. All these are liable to cause adduction contracture of the arm combined with a distinct tenderness over the insertion of these tendons. In these cases of sprain to the pectoralis major or latissimus dorsi, the pain elicited by outward rotation can be strictly located on the inner side of the arm close to the axillary fold.

It is also possible that extensive scar formation, even to the point of involving the nerve plexus, might follow tears of these muscles and tendons, and in consequence there may be neuritic symptoms of such severity as completely to overshadow the original lesion. This has been the case in one of the author's observations in which an acute strain or tear of the pectoralis and latissimus dorsi muscles, at their point of insertion, produced neuritic symptoms of a very marked degree extending over almost the entire brachial plexus.

There are also the various sprains of the shoulder joint itself, especially of the inner and anterior capsule, to be taken into consideration. Such sprains or tears of the capsule may occur in trauma not violent enough to cause a dislocation of the head; they are mostly induced by a forced motion of overabduction. The portion of the capsule most frequently and most violently exposed to strain by movement of the arms is the lower and inferior, or axillary, part (T. T. Thomas). One often finds, after reduction of a traumatic dislocation, a residual tenderness and swelling of the deltoid muscle. It is difficult to see in these cases to what extent the subdeltoid bursa may have participated in the joint injury, and also what part the neighboring muscles and tendons might have played. Protracted immobilization following injuries of the shoulder is likely to produce a picture of adduction contracture such as seen in subdeltoid bursitis. The condition of the deltoid muscle itself, however, will often give valuable information. Atrophy of this muscle in cases of sudeltoid bursitis is never extreme and does not reach the degree of inflammatory reflex atrophy seen in cases of arthritis of the shoulder joint.

Treatment.—There is almost unanimity of opinion that acute cases yield to fixation in splints or plaster casts.[2] As the condition persists, the prognosis of subdeltoid bursitis becomes more and more uncertain. Cases of not too long standing readily yield to manipulation by which

[2] Certain types of acute cases subside very frequently under heat and rest alone, even without abduction splint, motion being gradually instituted within a few days (Osgood, personal communication).

the arm is placed in abduction or outward rotation, if necessary, under an anesthetic. The forcible breaking up of adhesions is not to be recommended (Brickner) and it is preferable to stretch muscles gradually and to obtain the desired position of abduction and outward rotation by steps. Brickner advises a very simple method of obtaining this abduction, by keeping the patient in bed with the afflicted arm fastened to the pillow, and the bed so inclined as to allow the patient to slide down gradually. In this way, a position of abduction and outward rotation is gradually obtained. It is often necessary to manipulate under anesthesia and with relaxation of the muscles. The procedure then is, as a rule, a very simple one and does not require any violent effort. It is essential to procure immediate fixation in the desired position as soon as the latter is obtained, lest the advantage of the procedure be lost.

Within a very few days after manipulation, that is, as soon as the tenderness subsides, the after treatment should begin. When the arm is held up by a well-fitted splint, it is essential to see that the position of abduction and outward rotation should be lessened very gradually and only to the degree which the development of the abductors and outward rotators will permit, so that the active maintenance of any position obtained be secured (Dunlop). The writer has seen several instances in which the brisk letting down of the arm has brought about a recrudescence of the symptoms. In the rare instances in which the bursa is found distended by contents of serous or purulent nature, the aspiration of the fluid can be done by reaching the bursa through the lateral or anterolateral portion of the deltoid muscle.

There seem to be a number of resistant cases in which open operation becomes necessary. Painter considers all cases operative which show deposits in the supraspinatus tendon, as well as all those of six months' duration or more, which persistently resist conservative treatment. Baer reported 4 cases of excision of the bursa and considered this the method of choice in chronic cases; but the difficulty of this procedure has already been referred to. The method of removing lime deposits in the tendon is best followed with the technic given by Brickner. An incision is made over the external surface of the deltoid muscle from the middle of the acromion downward. After the division of the fascia, one proceeds through the muscle by blunt dissection. The roof of the bursa is now incised and the edges secured by fine forceps. In a similar manner, one proceeds through the floor of the bursa and underneath it the lime deposits imbedded in the supraspinatus tendon can be seen. This deposit is then carefully removed with a curette and the roof and floor of the bursa are sutured. The retracted halves of the deltoid muscle are allowed to fall together, and the wound is closed. The arm is put up in abduction and external rotation, and after treatment is instituted as soon as the wound is closed.

Cases of Subdeltoid Bursitis

Observed, 21.	*Treated*, 11.
	Conservatively, 9
	Operatively, 2
Onset	*Results*
Spontaneous, 5	Improved, 5
Twisting of the shoulder, 2	Cured, 5
Fall upon the shoulder, 4.	Not improved, 1.

Ages of patients, 19 to 70 years (Plate I, 1, 2, 3, 4, 5). Neither of the 2 operative cases showed a calcareous deposit, and the subsequent improvement probably was due as much to the fixation as to anything else.

Of the symptoms, pain on active and passive abduction beyond a certain level, and tenderness over the subdeltoid bursa below the acromion process or at a point in front of it, were by far the most constant features. Pain radiating into the arm and forearm was observed in 2 cases. In 2 cases, adhesions were felt breaking under manipulation. Deltoid atrophy was not prominent in any case. One of the cases developed following influenza. This case showed a distinct shadow over the head of the humerus at the seat of the subdeltoid bursa. Lime deposits were seen in the X-ray picture in 3 of the 21 cases. None of these cases was operated upon, but 2 of the 3 were treated conservatively with marked improvement. The treatment of choice for the majority of cases of subdeltoid bursitis is the elevation of the arm in splints in a position of abduction and outward rotation, combined with massage and physiotherapy. Passive motion should be carried out with the greatest care, and active motion should be encouraged very early and to the extent possible without causing pain. Manipulations should never be carried out with any amount of force, and two or three days of rest should be given before active motion is begun following manipulation. The operative treatment should be reserved for cases of long standing or cases showing lime deposits and not yielding to conservative methods.

Scapular Grating.—A degree of similarity exists between subdeltoid bursitis and a condition known as creaking or grating scapula; a disturbance of the free motion, at the upper inner angle, between scapula and thoracic wall. Boinet, in 1867, was the first to publish a case of scapular grating, and, after considerable period of obscurity, this condition was again brought to attention by publications of Kuettner and Axman (1904), Mauclaire (1905), Lotheisen (1908), Habermann (1911), and Lobenhoffer (1913).

Physiologically, there is audible friction at the upper inner angle of the scapula in 70 per cent of the cases. Under pathological condition,

LEGEND FOR PLATE I

Fig. 1.—C. S. Subdeltoid Bursitis.

Fig. 2.—C. S. After Conservative Treatment.

Fig. 3.—P. S. Subdeltoid Bursitis; after Forcible Correction.

Fig. 4.—P. S. Subdeltoid Bursitis; after Forcible Correction.

PLATE I

1

2

3

4

this friction may increase to a distinct shoulder creaking or grating, occurring upon the slightest movement of the shoulder and being audible or palpable when the ear or hand is placed upon the inner angle of the scapula. Up to 1913, there were reported, according to Betke, 31 such cases. The scapular grating is ascribed to a bursitis of the suprascapular bursa, situated at the upper inner angle of the scapula between the upper portion of the serratus magnus and the levator anguli scapulae. This bursa was found to be present in one out of every eight bodies examined by Groover. The scapular bursa, situated between the scapula and the subscapularis muscle, may also cause scapular grating, especially when rice bodies are present within the bursa.

Atrophy or congenital defects of the muscles between the scapula and the thorax are likewise considered as causes for scapular grating; finally, exostoses of a bony or cartilaginous nature have been found at the upper angle of the scapula which have given rise to the symptom of scapular grating. Habermann[3] reported 2 cases of the latter kind.

The symptoms are those of creaking or grating of the scapula on motion, accompanied by little or no pain, but a considerable weakness or heaviness of the arm is often complained of.

Treatment.—In the case of Lobenhoffer, the removal of a tumor on the bone, half as large as a cherry and containing a mucous fluid within its thick walls, brought about a cure. Betke and others used muscle transplants taken from the rhomboid muscles and placed them between scapula and ribs to overcome the friction and grating. Other and similar methods of muscle plasty were applied by Mauclaire, Kuettner, and Lotheisen. The writer has observed one case. The patient complained of pain in both shoulders. The pain was mostly elicited by elevation of the arms above the horizontal and was accompanied by a peculiar cracking in both shoulders between the middle and posterior part of the deltoid, where there was a distinct diastasis of the muscle fibers. In addition to this, a very distinct grating of the scapula was noticeable on the left side. This phenomenon was centered around the upper inner angle of the shoulder-blade near the origin of the levator anguli scapulae. It was audible as well as palpable. As it was not attended by any disturbing symptoms in the function of the shoulder, this feature of his disability was not subject to treatment.

[3] Attention is called here to manifestations of pain caused by pressure of the scapula against the ribs as described by Goldthwaite (Am. Journ. Orth. Surg., 1908, V). The pain is described as acute when the shoulder-blades are retracted backwards, but appears to be relieved when the shoulders are allowed to sag. Brachial neuralgia is, according to the same author (Am. Journ. Orth. Surg., May, 1909), occasionally caused by a sharp forward flexion of the supraspinous portion of the scapula.

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CHAPTER II

CONGENITAL DEFORMITIES OF SHOULDEF

BIRTH-PALSY

(Obstetrical Paralysis)

It has been known since the middle of the eighteenth century that a paralysis of the upper extremity follows at times the delivery of a child when complicated by certain obstetrical difficulties which necessitate forcible manipulation upon the upper extremity of the baby. In 1872, Duchenne, describing this condition, recognized it as a laceration process of the shoulder following forcible delivery, but the true anatomical basis of the lesion was not known to Duchenne himself. His observations, however, instigated a series of clinical reports in the following decades, which were inspired by Duchenne's work as well as that of Erb, and to the latter we also owe a classical description of the condition. The older observers were inclined to see the cause of the paralysis in a direct compression of the cords of the brachial plexus by the forceps. Later observers were inclined to consider the local injury to the shoulder joint as of prime importance, referring to the symptoms of paralysis as secondary to the shoulder-joint injuries. Finally, in the last two decades, investigations of a neuropathological nature were made, which brought forth a certain amount of new information bearing on the pathology of this condition. The latter investigations tended to show that the primary seat of injury was the spinal roots of the brachial plexus, especially the fifth and sixth, which are the ones most often concerned in the lesion. This distribution of the motor paralysis to the fifth and sixth cervical roots covers the great majority of cases of obstetrical paralysis and is now know as the Duchenne-Erb type of brachial palsy.

Excessive traction upon the nerve roots of the brachial plexus may result in rupture of some of the cords. Twenty years ago Stone described observations and experiments bearing out the influence of traction upon the roots of the brachial plexus. The experiments of Sever carried out on the cadavers of infants seem to show that traction upon the arm in abduction will put the upper cords of the plexus which arise from the fifth and sixth cervical roots under the greatest amount of tension, causing them to stand out like bowstrings among the rest of the plexus cords. Therefore, he concludes, a force tending to pull the head of the humerus laterally, which at the same time immobilizes the shoulder, is likely to bring about a rupture of these upper cords.

When the clavicle is intact, a very considerable force is necessary to injure the plexus, and in this case the suprascapular nerve is first to break.

In Sever's experiments, even with considerable force, the fifth and sixth cervical roots could not be completely torn, but were rather frayed out inside their sheaths; but when the clavicle was removed, the weight of the arm coming directly upon the plexus, much less force was necessary to produce the injury. Even then, according to Sever, it was hardly possible to put the eighth cervical and first dorsal roots on a stretch, much less to rupture them. Sever was also unable in his experiments to rupture the joint capsule, to separate the humeral epiphysis, or to produce a dislocation of the head of the humerus. This difference between the conditions with intact and broken clavicle had already been pointed out by Stoner, who found that there was little danger to the nerves from pressure of the clavicle, and that, when the clavicle was intact, breaking of the upper roots was very difficult; but when the clavicle was broken and the plexus alone held the shoulder, a lesser pull was sufficient to break the upper roots. On the other hand, these findings should be correlated carefully with the opposite views advanced by T. T. Thomas. It is not possible to go into a discussion of the etiology of this condition with any amount of clearness without carefully scrutinizing these two views, one of which is represented mainly by A. S. Taylor and J. W. Sever, namely, the Neurogenetic Theory; while the other is represented by T. T. Thomas and many others who adhere to the view that the joint injury is the primary factor in obstetrical paralysis. This joint theory has numerous adherents, among whom Sachs (1904) may be mentioned, who calls attention to the subluxation of the head; Whitman (1914) who finds that, in a large proportion of ordinary cases of birth-palsy, there are evidences of injury of the shoulder joint in the nature of strains or sprain; Lange (1912) who considers most cases of birth-palsy as due to laceration of the shoulder joint; and Vulpius (1914) who ascribes these cases to injuries to the epiphyseal cartilage. T. T. Thomas considers as the primary and most essential cause of the trouble the injuries to the shoulder joint. When this injury is remedied early enough, he says, one need not be concerned about the paralysis. The joint injury is primary and the paralysis secondary, and the latter is caused by the inclusion of the branches of the brachial plexus in the axillary inflammation consequent upon the joint injury. He bases his views upon facts of an experimental as well as a clinical nature. Clinically, almost all shoulder-joint injuries are associated with palsies; and the disappearance of paralysis which is almost regular in the Duchenne-Erb, or so-called upper arm type, is to him a proof of the absence of a rupture of the nerve roots. He also points out that, in obstetrical paralysis, there is a severe, if not a complete, paralysis of the whole limb, and takes issue with the Duchenne-Erb distribution of paralysis (fifth and sixth cervical roots).

It cannot be denied that extravasation of blood and synovial fluid into the axilla will lead later to cicatricial tissue, all of which will probably be absorbed in time, and this would account for the disappearance of the paralysis. But the most perplexing discrepancy is seen in the experimental findings. Contrary to Sever's experiments, Thomas finds that forceps traction cannot be responsible. In the first place, because, when traction of the

arm would be applied, the head is already delivered; second, because there are a number of cases of normal delivery included in the series of birth-palsies (32 of 471 reported by Thomas and Sever); and, finally, T. T. Thomas' experiments show that even very extreme traction of the head with forceps was not able to produce any visible rupture at any point of the plexus.

When we again consider the experiments of Prout, who found rupture of the perineural sheaths immediately surrounding the nerve bundles and described minutely the histological changes occurring immediately after a rupture of the neuraxes in birth-palsy, and finally the reports of A. S. Taylor of operative findings revealing rupture of the fifth and sixth cervical roots, one might be led to think that the neurogentic theory is proved without doubt. But against this unqualified acceptance, there stand out several questions in the controversy which have never yet been answered satisfactorily by the adherents of the theory of nerve injury. In the opinion of G. G. Davis, the shoulder contracture following the birth-palsy is proof positive that there is a peri-articular lesion. Why is it that the flail-joint, which characterizes deltoid paralysis, due to anterior poliomyelitis or other causes, is never found in cases of birth-palsy?

It is maintained by the followers of the neurogenetic theory that the subluxation is not noticeable until at least three weeks after birth; but it is hard to conceive that the posterior dislocation of the humerus, as seen in some cases, is entirely a paralytic deformity. To sum up, therefore, it must be conceded that there are discrepancies of fundamental nature and that the findings of the different observers cannot all be explained fully by either of the two theories. In the face of positive and trustworthy observations, both of the root lesions and the local joint complications, one must assume that neither of the theories can be accepted to the entire exclusion of the other, and there seems to be no reason why a gross lesion of the shoulder joint might not, in a number of cases, be combined with injuries to the nerve roots.

Clinical Pathology—*Upper Arm Type.*—Shortly after birth, sometimes within a few days, it is noticed that the affected arm hangs limply at the side of the body. The elbow is held in slight flexion and the forearm in pronation. The child is completely unable to abduct the arm. During the first week, there may be some swelling or tenderness in the region of the deltoid. This, however, usually subsides, and there remains only a paralysis of the deltoid and supraspinatus muscle, occasionally complicated by paralysis of the biceps, coracobrachialis, infraspinatus and supinator longus. With the existing inability of abduction and external rotation, a contracture soon develops, due to the unopposed action of the adductors and inward rotators of the shoulder. But this paralysis of the deltoid and supraspinatus is, in the great majority of cases, only temporary, and with the repair of the injured nerves, these muscles take up function again. Still, at the time when nerve repair is completed, a condition of contracture in adduction and inward rotation is already established and remains as the permanent disability of the shoulder. The internal rotation is maintained mostly by the

subscapularis muscle, while in the adduction the contracted pectoralis major and latissimus dorsi are mainly involved.

Some cases undoubtedly go on to complete recovery without the establishment of residual contracture, but in the large majority of cases of this group, the adduction and inward rotation develop as residual deformity. Again, there are cases in which there is no repair of the nerve lesion and, consequently, no recovery of the paralyzed muscle. But these cases also form a small minority, so that one may say that the typical course of the upper arm type of birth-palsy is that of a temporary paralysis followed by a permanent contracture.

In a certain number of cases, the contracture is complicated by subluxation or dislocation of the humerus. The displacement is posteriorly and slightly upward, so that the head of the humerus lies directly below the spine of the scapula. If this condition is to be explained—according to some observers—as the result of muscular contraction, it must be assumed that the contracted subscapularis muscle forces the head backward and that the relaxed posterior capsule of the joint and the relaxed tendon of the paralyzed supraspinatus muscle permit the head to leave the glenoid cavity and to appear posteriorly and slightly below the acromion process. The latter is often hooked downward over the glenoid fossa so that it forms a considerable obstacle to the replacement of the dislocated head.

The statistics on the frequency of posterior dislocation or subluxation are rather misleading. In any degree of paralysis of the deltoid muscle, the relaxed capsule is liable to permit a state of subluxation without allowing the head actually to give up contact with the glenoid fossa. But this is not the condition which prevails in the cases of dislocation associated with birth-palsy. There is no relaxation of the shoulder joint. One is decidedly impressed by the rigidity of the contracture and the permanency with which the head is placed subspinous and retrospinous, in its posterior dislocation.

The Whole Arm Type.—In a minority of cases of obstetrical paralysis, the lesion extends throughout all the cords of the brachial plexus, involving in the paralysis not only the shoulder, but also the arm, the forearm, and the hand. In these cases, the paralysis of the flexors and extensors of the fingers, and a decided atrophy of the intrinsic muscles of the hand, is liable to persist together with that of the muscles of the shoulder. The lesion involves not only the fifth and sixth cervical roots, but also the lower cords of the plexus, especially the ulnar and median nerves, to the eighth cervical and first dorsal roots. The extremity shows the same position of contracture in the shoulder as do the cases of the upper arm type, but, in addition to this, there is a pronation contracture of the forearm, and often a drop-wrist with very limited motion of the fingers. The elbow is usually held in slight flexion, the pronated forearm crossing the abdomen (stomach-ache position). This group forms a small minority of the cases.

The Fore Arm Type.—In other cases, however, there is a total involvement of the upper extremity, followed by quick recovery of the muscles of the upper arm or Duchenne-Erb group, while the lower segments of the

plexus remain more or less permanently paralyzed. The resulting paralysis is then that of the inferior radicular group, a form which has been described first by Mme. A. Klumpke (1885).

While, in the upper arm lesion, no sensory disturbances are present, this is not the case in the whole arm nor in the lower arm type. The anesthesia is complete usually along the forearm extending beyond the elbow in a more or less irregular line, involving the upper arm only occasionally. The internal aspect of the arm as well as the shoulder are almost always found intact, as long as the lesion is strictly limited to the brachial plexus. This is to be explained by the distribution of the intercostohumeral nerves and the internal cutaneous nerves of the arm (Klumpke). Another symptom, not found in the Duchenne-Erb type but regularly in the inferior radicular type, is the oculopupillary signs of myosis (pupillary contraction) and of retraction of the eyeball. These symptoms are produced by lesion of the inferior roots and especially of the first dorsal, according to Klumpke's experiments on dogs. Of the motor nerves, the ulnar is more severely involved than the median. In the cases reported, the paralysis of the forearm muscles as well as that of the hand had remained permanent, and the outlook for improvement in cases of this type is even less favorable than it is in cases of whole arm type. This group is more exceptional than the other two, and T. T. Thomas in his series records only 2 cases. The atrophy may be considerable in extreme cases, but it never reaches the degrees seen in infantile paralysis.

As regards complications in and surrounding the shoulder joint, fracture of the clavicle as well as separation of the humeral epiphysis occasionally are seen. The fracture of the clavicle greatly facilitates, as experiments seem to show, a rupture or tear of the plexus, especially of the lower cords. The displacement of the head of the humerus is, as a rule, posterior, and reference has already been made to the details of this complication. Anterior displacement of the humerus, however, has been seen and reported.

In the earlier literature, we find references to congenital dislocation of the shoulder. This, if it exists at all, is certainly an extremely rare deformity. Porter (1900) reported from the literature 29 cases of congenital dislocation of the shoulder. A close scrutiny of this series, however, showed that a majority of the cases were extremely doubtful and that they apparently belong to the group of birth-palsy or possibly of traumatic dislocation caused by injury during birth. Such cases are reported by Robinson, who has seen 2 cases of congenital dislocation of the head of the humerus, one posterior and subspinous, the other posterior.

Lewis (1895) reported a case of subspinous and posterior dislocation of the shoulder, then considered congenital, but apparently a complication of obstetrical paralysis. Some observers make a distinction of the dislocation into different types; a paralytic dislocation due to the paralysis of the deltoid and the contracture of abductors and inward rotators, a traumatic dislocation occurring during delivery, and a true congenital dislocation concurrent with the paralysis and distinguished by malformation of the head of the humerus and the glenoid fossa (Stone). Such distinctions, however,

do not shed much light upon this vexed question. The only positive evidence of congenital dislocation of the shoulder which might withstand all criticism is a missing or rudimentary glenoid cavity, or a distinct malformation of the humeral head.

Smith, quoted by Hoffa, reports 2 cases of subcoracoid dislocation of the humerus on both sides in which anatomical findings were obtained. The head of the humerus was found located at the coracoid process, the glenoid cavity on the left side was missing and on the right side rudimentary. A new articular surface had been established on the under side of the coracoid process, with which the head of the humerus articulated. The humerus itself was thin and atrophic. The long head of the biceps originated at its normal place at the lower border of the glenoid fossa. The second case of Smith's was one of subacromial dislocation with a new articular facet located at the neck of the scapula.

A case of double congenital dislocation of the shoulder is also described by Kuester in a one-year-old child. Other cases reported under that heading are doubtful and probably represent dislocations accompanying birth-palsy. In cases of severe whole arm type of obstetrical palsy, a contracture of the short head of the biceps and the coracobrachialis muscle is not uncommon. In one of the cases observed by the writer, the contracted biceps caused a flexion contracture of the elbow and an anterior dislocation of the head of the radius. Pronation contracture of the forearm occasionally complicates the inward rotation of the humerus so that the whole extremity appears to be rotated strongly inward with the palm pointing backward and outward (the policeman's tip position).

Sever's statistics show the following distribution:

Upper arm type	400
Whole " "	64
Mixed " "	9

Sever found no deformity and no displacement of the humerus in the X-ray in all cases under one year. He also found that the hooking of the acromion and the posterior subluxation of the humerus appear later.

Prognosis.—A small minority of cases recover almost completely after three months, and it is impossible clinically to establish the definite extent of the lesion at an early date. Only after the lapse of a year or more does the permanent extent of the paralysis become apparent. In all cases of the upper arm type, the prognosis may be said to be good, while in all cases of lower arm type and of the whole arm type, the prognosis is bad, as regards restoration of function.

Treatment.—The treatment must start at the earliest possible date. Mild cases will improve promptly on conservative treatment, consisting of proper splinting of the extremity in abduction and outward rotation; contractures will in these cases also yield to simple stretching with or without anesthesia. The splint applied must hold the arm in proper position, and its proper application should be constantly supervised. The after treatment begins immediately. It consists in massage and passive motion,

and, in addition to it, in active motion in older children. Cases with severe contractures which do not yield to bloodless stretching require an open operation for the relief of the contracture. The best method is the one advocated by Sever; the technic of it is given here as follows:

An incision is made from the acromion downward over the anterior aspect of the shoulder joint. After dissection of the fascia, one proceeds bluntly between the deltoid and pectoralis muscle, the former being retracted outward and the latter inward. The upper edge of the pectoralis muscle is then incised downward at or near its tendon of insertion, in order to gain better approach to the head of the humerus. The subscapularis tendon is then located as it swings around the head of the humerus close to the capsule, to reach the greater tubercle. A blunt director is then passed underneath the tendon between it and the capsule and the tendon is severed over it. At this moment the arm will usually allow of complete outward rotation. The retracted muscles are allowed to fall together, the wound is closed and the arm is put up in plaster in abduction and outward rotation. There it should remain for two weeks, then the cast should be replaced by a splint, and exercises and massage should be instituted. In Sever's operation the capsule is not opened. If the coracobrachialis muscle and the short head of the biceps are tight, these tendons are severed also. For the relief of the inward rotation, Sever's operation is the method of choice and undoubtedly the most valuable. Other authors advocate the osteotomy of the humerus with subsequent outward rotation (Stone, Lange, Vulpius). The reduction of the dislocation of the humerus by bloodless manipulation will be possible only in a limited number of cases. In the majority, especially in those in which bony obstacles, such as hooking of the acromion, prevent reduction, an open operation with arthrotomy must be done, and the acromion process must be severed with the osteotome in order to allow the replacement of the dislocated head. In order to hold the humeral head in place, Phelps advocated the use of arthrodesis of the shoulder joint. He deepens the glenoid cavity, pares off a portion of the humeral head and then obtains fixation by stitching the relaxed posterior portion of the capsule.

Plexus Operations.—The indications for operative repair of the injured nerve roots are a matter of considerable uncertainty. Theoretically, such interference would be indicated in all cases of birth-palsy in which there is more or less complete paralysis, especially in those cases which extend to the forearm and in which the first few weeks do not bring any spontaneous return of the muscle function. It is very difficult to decide how long one should be justified in waiting. Most of the observers agree that, in severe cases, one should not wait more than a few weeks, and if no sign of improvement should appear within that time, then at least the exploratory operation and the dissection of the injured nerve roots would be indicated. The technic of this procedure is given by Taylor as follows:

An incision is made along the posterior border of the sternocleidomastoid muscle obliquely downward. The platysma and the deep fascia are divided, exposing the omohyoid muscle and the deep subscapular

vessels. The latter are double tied as is also the transversalis colli, and the thickened and adherent deep fascia is divided and the nerves are exposed. The damage will usually be found at the junction of the fifth and sixth cervical roots. These appear indurated. The mass of scar tissue should then be incised with a sharp scalpel or tenotome. The use of scissors in cutting the nerves and the handling of nerves with forceps is to be condemned. After incision of the cicatricial tissue, the nerve ends are then brought together by lateral sutures of fine silk, the sutures being passed through the nerve sheaths only. The nerves are then wrapped with Cargile membrane around the anastomoses.[1] The omohyoid muscle is sutured with catgut. A plaster-of-Paris splint is then applied which keeps the head and shoulders approximated to release tension. In some extensive lesions, it is necessary to divide the clavicle and the subclavian muscle. By elevating the shoulder and inclining the head toward the plexus, it is possible to bridge a distance up to 3 cm. In some instances, there is a buckling inward of the torn perineural sheath interposing a mass of connective tissue which prevents regeneration of the torn neuraxons (A. S. Taylor). One specimen of J. J. Thomas' showed incomplete rupture of the perineural sheath with hemorrhage. In this case, it could be assumed that spontaneous recovery would have followed the nerve injury. Usually, the fifth and sixth cervical roots are found imbedded in fibrous tissue; more rarely, the seventh and eighth. In Thomas' report of 9 cases, 2 died soon after operation, and of the remaining 7, 3 showed improvement. This author considers the time of the operation to be from 6 to 12 months of age. Sharpe's reports cover a series of 56 operations, and he failed to find a nerve lesion in only 1 case. He is, therefore, an ardent advocate of the early plexus operation; if possible at the age of one month, since there is then less formation of scar tissue and less retraction of nerves.

Reviewing these operative reports on the brachial plexus, especially the statistics of Sharpe, one cannot suppress the argument that, in a child one month old, there is no possibility of judging the eventual spontaneous reappearance of motion through natural repair of the damaged roots. In the writer's series of 17 cases of birth-palsy, the types represented were as follows:

Upper arm type	13
Whole " "	4
Lower " "	none

Of the upper arm type, 7 cases had difficult delivery or birth trauma recorded in the history. In all of the whole arm type cases (4), birth trauma is reported. This trauma consisted uniformly in the pulling of the arm laterally. Of these cases 2 of the upper arm type showed a dislocation of the humerus and 1 of the whole arm type a dislocation of the head of the radius.

[1] As a result of war experience, it is now generally conceded that wrapping nerves with foreign material causes unnecessary adhesions and rather impedes recovery.

SUMMARY.—Of the 17 cases seen and examined, 10 were treated.

Conservative Treatment: 4 cases of upper arm type.
1 case of whole arm type.

Treatment consisted in redressment under ether—1 case. Application of splint in abduction and outward rotation—4 cases:

Results: Good in 3 cases.
Fair in 2 cases.

Operative Treatment.—Sever's operation was carried out in 2 cases of upper arm type, and in 1 case of the whole arm type.

Open reduction of the shoulder was done in 1 case of the upper arm type.

Plasty of the paralyzed elbow joint prior to arthrodesis of the shoulder in whole arm type—1 case.

Operative Results: In regard to correction and function:
Good in 3 cases.
Fair in 1 case.
Poor in 1 case.

The poor result was due to interruption of the treatment.

Total:	6 Upper arm types	6 good results.
	4 Whole arm types	3 fair results.
		1 poor result.

The case of the posterior dislocation of the humerus was that of a boy 9 years old. The history records instrumental delivery with palsy noticed within 4 days, involving the entire extremity. At the age of 1½ years, he could flex the fingers and the wrist but could not extend the wrist. He could not abduct the arm and shoulder. The patient, on admission, had adduction and inward rotation contracture of the shoulder. There was also a posterior dislocation of the head of the humerus with hooking of the acromion, and a residual paralysis of the musculospiral nerve with inability to extend the wrist and fingers. There was no deltoid paralysis. The forearm was held in pronation contracture. The operation consisted in open reduction of the dislocated head from a posterior incision with osteotomy of the acromion, followed by stretching of the subscapularis tendon. The wrist drop will have to be taken care of by arthrodesis and the pronation contracture by resection of the pronators.

Another case was one of the whole arm type in a boy who had been seen, off and on, between the ages of 8 weeks and 4½ years. At 8 weeks, he had complete brachial palsy of the entire right upper ex-

tremity, no motion in either shoulder, elbow or fingers. Six months later, his motion had greatly improved. Flexion and extension appeared in hand and fingers and some power of abduction in the shoulder. When the boy was 4½ years old, his father consented to treatment. At this time, the residual deformities and paralyses had been well established. The flexion of the fingers was good, the extension poor, the forearm was held in pronation contracture, biceps and triceps were working well. Elevation of the arm was possible to the horizontal by action of the deltoid. There was, however, a contracture of moderate degree of the pectoralis and subscapularis muscles. The X-ray showed a dislocation forward of the head of the radius. The operative treatment consisted: (1) in Sever's operation for the relief of the inward rotation contracture; (2) in arthrodesis of the wrist for the drop wrist; (3) in the operative reduction of the dislocated head of the radius.

In reviewing this case, one cannot escape the conclusion that a fracture of the right clavicle sustained at the time of the birth injury had something to do with the extent of the paralysis. The originally very extensive paralysis cleared up to a remarkable degree, leaving practically nothing except a partial paralysis of the musculospiral nerve. There were, however, residual contractures in the shoulder, namely, adduction and inward rotation, and residual pronation contracture of the forearm.

A. G., a girl 14 years old, presented herself for treatment for deformity and disability of the right arm. The history states that on the 3d day after birth an extensive palsy of the right arm was noted. The entire extremity was found shortened, the upper arm lacking 2 inches and the forearm also 2 inches, in measurement, compared with the sound arm. There was extreme inward rotation in the shoulder together with adduction contracture so that the arm could not be lifted away from the body more than about four or five inches. There was distinct action of the deltoid. The forearm was in extreme pronation contracture to the extent that the palm was turned forward being rotated almost in a full circle from the position of full supination. Active flexion of the elbow was impossible.

This case was treated operatively; first, for the relief of the extreme pronation contracture, a resection of the pronator radii teres was done as well as a section of the pronator quadratus. The hand was then rotated back in a position which came within 40° of full supination. This was as much as was compatible with the undisturbed circulation of the forearm; then, the adduction and inward rotation contracture of the shoulder was remedied by Sever's operation of sectioning of the subscapularis tendon to which the severance of the coracobrachialis and short head of the biceps was added (Plate II, 3, 4; III).

CONGENITAL ELEVATION OF THE SCAPULA

(Sprengel's Deformity)

Attention was first called to this condition in the seventeenth century (Underberg, 1693) when 3 cases of congenital elevation were reported as dislocation of the scapula. A similar case was reported by Eulenburg (1863). Earlier reports of this nature were made by Willet and Walsham in England and by McBurney and Sands in America, the latter classifying the condition as a congenital deformity due to malposition of the scapula. Eulenburg in his report calls attention to an exostosis at the upper border of the scapula as well as to the inability of the patient to abduct the arm beyond the horizontal level. A case of Heinecke, 1886, also deserves mention as the author believed that he had reduced the scapula by manipulation. The deformity bears the name of Sprengel's Deformity because of this author's publication (1891) in which he gave a clear description of the condition, reporting 3 cases of the ages from 1 to 7 years. In these he found one scapula 2 or 3 cm. higher than the other. The motion of the arm was impaired and 1 case showed a small exostosis which this author considered to be a rib, and for the presence of which he ventured no explanation; but Koelliker, immediately following, called attention to the fact that this bony substance takes its origin from the inner border of the scapula developing from a bony nucleus attached to this inner border.[2]

According to the statistics of Zesas (1906), there were 100 cases reported in the literature at that time; 48 in males, 34 in females, while in 18 the sex was not given. Of these cases, only 11 were bilateral. The ages of the patients ranged from 3 months to 41 years. In order to understand the pathology of this condition, it is necessary to refer to the normal topographical relations between the scapula and the vertebral column. The upper border of the scapula reaches up to the second rib, the lower angle is situated at the level of the seventh and eighth rib. The root of the spine of the scapula at its vertebral border is situated at the level of the fourth rib and opposite to the third thoracic spine. The normal scapula has a triangular shape with a long vertical and a short horizontal diameter. In an embryo of 11 mm. length, the scapula lies opposite the lower fourth cervical vertebra and the first and second dorsal vertebrae. In the course of development, the scapula migrates caudalward so that in an embryo of 14 mm. length, less than one half of this bone lies higher than the first rib. Furthermore, with the growth of the embryo, the scapula changes its shape from a greater horizontal diameter to a greater vertical diameter.

[2] A case of elevation of the scapula in a boy of eleven is reported by Ridlon. The deformity developed at the age of one year and followed whooping cough. It was found to be due to spastic contracture of the trapezius, levator anguli and rhomboid muscles and disappeared entirely under anesthesia.

In the full-term human fetus, there still exists a high position of the scapula which appears also much more nearly in the sagittal plane than it does in adults (Chivietz). The whole upper limb, in fact, is in its origin a cervical appendage and retains this position in fetal life. It is not until the beginning of extra-uterine life that mechanical influences come into play which produce a permanent modification of the fetal condition. According to Dwight, the scapula of man is remarkable for the development of the infraspinous part making the vertebral border very long and the inferior angle very prominent.

In congenital elevation of the scapula, certain changes occur in the configuration of the bone as well as in its relative position to spine and ribs. These alterations consist first in a decrease of the vertical diameter and an increase of the horizontal, thus giving the bone the character of a reversion to a lower type or of the retention of a more fetal form (developmental arrest). Another anatomical change noticeable in this deformity is the curving forward of the superior border and of the supraspinous part of the scapula. According to Horwitz, this anomaly is seen in about 18 per cent of the cases. The upper outer angle of the bone is also drawn out presenting a hooklike appearance, according to the observations of Koelliker and Sprengel. A large percentage of cases also show fibrous or cartilaginous attachments of the scapula to the vertebral column. Another series of cases show bony articulations between the scapula and the vertebral column. This articulation usually runs from the upper inner angle of the scapula or from its median border to one of the transverse processes of the cervical spine. It represents a bone of more or less triangular shape resting upon the scapula, with the apex pointed toward the transverse process of the spine.

About the nature of this bony articulation, many views have been expressed. It was argued that this bone might be the outgrowth of the spinous process or that it might be formed both by the spine and the scapula. In the opinion of Willet and Walsham, this bridge of bone is an abnormal development of the suprascapular epiphysis normally existing as a narrow bridge of bone along the posterior border of the scapula and corresponding to the suprascapular bone of some of the lower vertebrates. Other authors believe that these articulations are to be considered as degenerated muscle bands with centers of ossification appearing in the rhomboid muscles.

Other features of this deformity are defects and anomalies in ribs and vertebrae. Instances of this kind are reported by Roger, Graetzer, Horwitz and many others. Such defects in the normal development of ribs seem to point to a more elementary developmental error than a mere failure of the scapula to descend would represent. Of the muscular changes seen in congenital elevation of the scapula, the most noticeable are those of the trapezius muscle. Complete absence of this muscle has been reported (Kirmisson). It is very often found contracted and in many cases plays a part in the asymmetry of posture of the head and in the development of a scoliosis.

LEGEND FOR PLATE II

FIG. 1.—F. J. BIRTH-PALSY WITH POSTERIOR DISLOCATION OF THE SHOULDER.

FIG. 2.—F. J. BIRTH-PALSY WITH POSTERIOR DISLOCATION OF THE SHOULDER.

FIG. 3.—F. J. AFTER OPERATIVE REDUCTION IN CAST.

FIG. 4.—F. J. AFTER SECONDARY OSTEOTOMY OF THE HUMERUS.

PLATE II

1

2

3

4

LEGEND FOR PLATE III

Fig. 1.—J. S. Birth-Palsy with Posterior Dislocation of Humerus.

Fig. 2.—J. S. X-ray of Dislocated Shoulder. Note Small Head and Shallow Socket.

Fig. 3.—A. G. Birth-Palsy; Whole Arm Type. Note Extreme Inward Rotation.

Fig. 4.—A. G. After Resection of Pronator and Internal Rotators of Shoulder.

PLATE III

1

2

3

4

Kayser reported complete absence of the sternocleidomastoid muscle. A defective pectoralis muscle has also been noticed. Other muscles involved occasionally are the serratus magnus, the levator anguli, the latissimus dorsi, and the rhomboid muscles. Deformities of the humerus and clavicle have been seen and reported. Hibbs mentions a case of shortening of the humerus and the clavicle, the shortening of the humerus being too excessive to be classified as a mere atrophy from disuse. Considering the changed position of the scapula, it is not difficult to account for a shortening of the clavicular bone.

A complete dissection of a case of congenital elevation of the shoulder-blade is described by Fetterolf and Arnett. They report such extensive anatomical changes that a short review of their findings does not seem out of place. The scapula was normal in size. On its vertebral border, just below the spine, there was a triangular facet articulating with a bony projection from the sixth cervical vertebra. The articulation was partly responsible for the restricted upward movement of the arm. The osseous growth consisted of a strong, markedly curved process of bone 4 cm. in length which was of a partially movable type, and at its junction with the scapula it was furnished with a capsule containing joint fluid. The right laminae of the fifth, sixth, and seventh cervical vertebrae, with which this bony process articulated at the other end, did not join those on the other side to complete the neural arch so that a condition of rachischisis existed.

The muscle changes were striking. The trapezius consisted of two portions, an upper one which was more or less normally developed and a lower one which was more or less atrophic and consisted mainly of fibrous tissue. The upper part had its usual origin at the occiput and the cervical spine; the lower arose from the thoracic vertebrae, its fibers intermingling with those of the rhomboid. The levator anguli scapulae, slightly below normal size, had a Y-shaped insertion into the scapula, one arm fastening into the superior angle and the other into the articulation. The rhomboids were absent, being represented only by some connective tissue. The serratus magnus, instead of fastening to the vertebral border of the scapula, went beyond, interlacing its fibers with those of the rhomboids. There were also a number of anomalous muscle slips.

In connection with this deformity, all kinds of complicating anomalies and deformities have been observed, such as club-foot, shortening of the femur, defects of hand and fingers, maldevelopment of the whole upper extremity, cleft palate, etc. In the case of Drenkhahn, there was found a synostosis of radius and ulna. Bolten reports a case complicated with total defect of the radius and club-hand.

The clinical symptoms of this deformity center largely upon the pathological position of the scapula itself. Combined with this, there is often a scoliosis varying from slight to very marked degree (Kirmisson, Mohr). The curvature is usually situated in the lower cervical and upper dorsal spine producing a compensatory curve in the dorsal

and lumbar section. The fact that scoliosis exists only in a certain percentage would make it improbable that it is directly due to the high scapula. Nove-Josserand considers the scoliosis as an incidental deformity caused by the same general arrest of development. In the same way, torticollis is seen in a certain percentage of the cases either with or without facial or cranial asymmetry. Nor does this seem to be directly caused by the high position of the scapula.

In at least one-half of the cases, the function of the shoulder as regards motion is found to be unimpaired. Where it is impaired, it is the abduction of the arm which has suffered, the patient being unable to abduct beyond the horizontal. This can be readily understood if one considers that motion in the scapulohumeral joint is possible only to the horizontal and that beyond this plane, the scapula itself must rotate in order to allow the arm to be raised from the horizontal position to the vertical position upward. This rotation is taken care of normally by the combined forces of the trapezius and serratus magnus muscles. When these muscles are contracted or shortened, such rotation of the scapula will become impossible.

But even in cases of bilateral deformity, the range of motion of the arm is not necessarily restricted to a marked degree. In these bilateral cases of Sprengel's deformity, the high position of the scapulae gives the shoulders the appearance of being forcibly drawn up. The neck appears short and the normal contours of neck and shoulder line are changed. They do not show the gentle slope seen in the normal erect posture, but the shoulders form more nearly a right angle with the side of the neck.

As to the pathogenesis of this deformity, a number of theories have been formulated. Sprengel himself considered the position of the fetus in utero as responsible for the deformity, not recognizing that there was a failure of the scapula to descend. The shape of the superior border of the scapula, especially the forward inclination of the suprascapula, is considered by Rager to be the reason for the incomplete descent, while Lange believes the contraction of the trapezius muscle to be instrumental in this deformity. Some hold the defect of the trapezius muscle responsible (Kausch, Hoedlmoser, Neumann); others speak of poliomyelitic paralysis (Bloch). Of all the theories, that of developmental arrest seems the most plausible and is most generally accepted. Those authors, like Chivietz, who have paid close attention to the ontological development of this bone adhere to the theory of the reversal to lower type or retention in a fetal position.

One word must be said about what some authors term a pseudo-Sprengel deformity. They are inclined to distinguish between a true congenital elevation in which there is a primary contraction of the muscles with disturbance of function, and a pseudo-Sprengel deformity in which the bone is held in place by bands or exostoses and in which there is no disturbance of function nor contraction of muscles. This

LEGEND FOR PLATE IV

Fig. 1.—E. T. Winged Scapula.

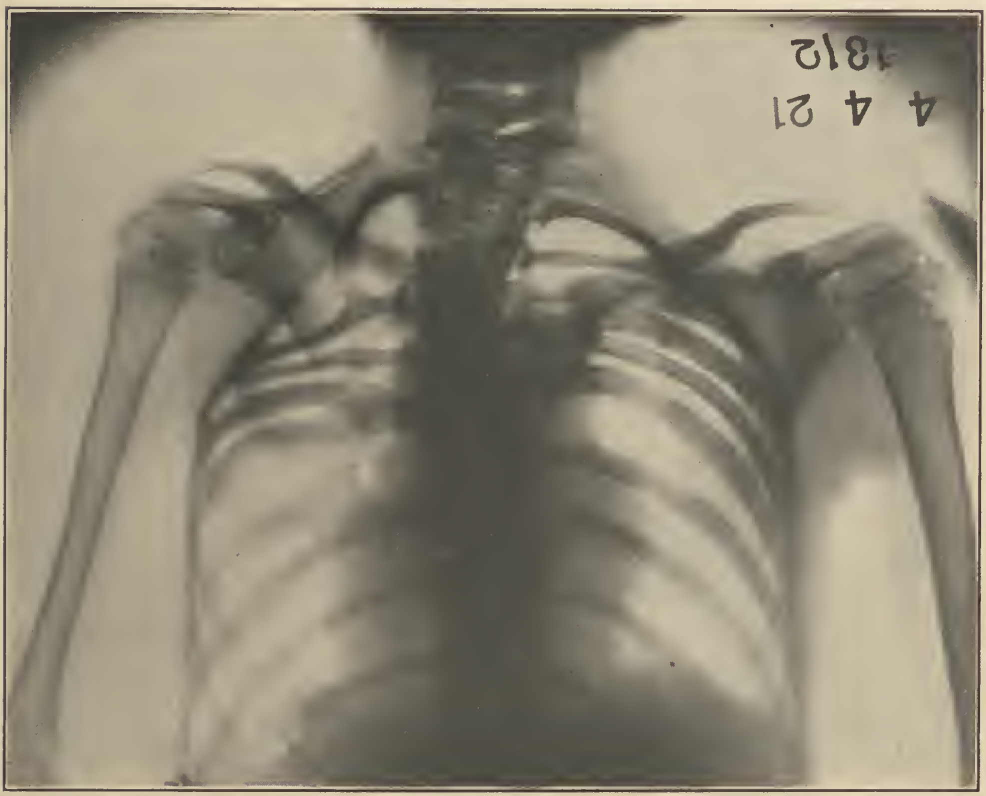
Fig. 2.—H. A. Congenital Elevation of Scapula.

Fig. 3.—H. A. X-ray, Showing Elevation of Left Scapula, Wedge Formation of Vertebra and Fusion of Ribs.

PLATE IV

1

2



3

distinction into different groups and subdivisions seems hardly justified and is likely to bring confusion in the conception of this condition.

Treatment.—In milder cases, treatment by gymnastic exercises and stretching of the contracted muscles was carried out successfully by Goldthwaite, Painter, Gibney, and others. In cases in which conservative methods do not produce results and where the contractures of the muscles are severe enough to interfere considerably with the function of the arm, or in which a considerable functional damage is caused by bony adhesions and articulations, operative methods are indicated. The removal of articulations has been carried out repeatedly (Brackett, Lovett, Jones, Wilton, and Rough).

Technic of Operation for Removal of Articulations.—Incision over the vertebroscapular articulation, resection of bone bridge, freeing of scapula. The trapezius and rhomboid muscles have to be dissected off their places of insertion. This, in a number of cases, will render the scapula freely movable so that it can be held down in proper position (Wilson and Rough). In some cases, the hooked superior angle of the scapula had to be resected (Koelliker, Froelich, and others). After division of trapezius, which often consists of dense fibrous bands in its lower portion, and of the rhomboids and the levator anguli, the cartilaginous bands attached to the upper inner angle of the scapula are then removed. This mobilizes the shoulder-blade completely and it may then be depressed downward and reduced (Ashhurst). Gill found in his case a plate of bone after dividing the skin and fascia. It extended from the middle of the vertebral border to the sixth cervical spine. Even after complete removal of this articulation, the scapula could not be brought down to normal position until the trapezius was separated from the posterior portion of the spine of the scapula, and the two rhomboids as well as the levator anguli were also detached. In addition, he had to loosen the supraspinatus muscle from its posterior attachment and, lastly, he had to overcome the obstacle offered by the hooking of the external angle, by resecting the entire upper portion as far as the suprascapular notch. These reports show that operative correction of the deformity may be extremely difficult and often calls for very extensive resections of both bone and muscles. Such extensive interference is hardly justified unless the deformity entails grave functional impairment in the use of the shoulder.

Case Reports.—K. K., 3 years; complaint of patient is a shortened and rather stiff neck. On examination, both scapulae are found high, their upper border opposite the lower cervical spine. This shortness of the neck is explained in the X-ray by wedge formation of the cervical vertebrae as well as by the high position of the scapulae. There is no limitation of motion of the humerus but the side motion of the head is rather restricted. Under gymnastic treatment, this restriction of motion improved, however, to a considerable extent.

K. R., 9 years; a sister of the patient just reported. This child also shows a short neck with restriction of rotation and lateral motion of

the head. The X-ray shows a lack of bony union of the neural arches of the cervical spine, with flattened vertebral bodies. There is fusion of the ribs in two places, both scapulae are high. On gymnastic treatment, the motion of the head improves so that rotation becomes comparatively free while side motion is still somewhat restricted.

P. Y., 6 years. At the age of 5 years, it was noted that the patient's left shoulder stood higher than the right and that there was some restriction in the elevation of the arm. The examination shows the left shoulder elevated 2 inches and rotated forward. The trapezius and levator anguli are contracted. There is no articulation of the scapula with the vertebral column. The X-ray shows the scapula elevated 2 inches. It is of apparently normal configuration and has no abnormal bony attachment. There is a distinct fissure in the dorsal spine. It is most pronounced in the first dorsal vertebra, the body of which is divided into 2 cuneiform halves, the left one being higher and carrying with it the first rib. Functionally, there is slight lack in active elevation of the arm though passive motion is perfectly free. Patient is treated by massage and gymnastic exercises.

H. A., 1½ years. Elevation of the left scapula 1½ inches. Abduction of the arm fairly free but not complete. The X-ray shows elevation of the left scapula with forward curving of the upper border. It shows also the following anomalies: fusion of the third and fourth rib on the right side; fusion of the seventh and eighth rib on the left side, and wedge formation of the sixth cervical vertebra. The case is also complicated by congenital contraction of the fingers and of the wrist, with syndactylism.

In all four cases reported, vertebral anomalies, fusion of the ribs, etc., were present, and in no case was the elevation of the scapula the only deformity existing (Plate IV, 2, 3).

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CHAPTER III

PARALYSIS OF SHOULDER AND ELBOW

PARALYSIS OF SCAPULOTHORACIC MUSCLES

(Muscle Dynamics of the Scapula)

The movements of the scapúla may be either translatory or rotatory. In the first case, all points move parallel to each other—up and downward, back or forward motion; in the second case all points rotate about either the inner or the outer upper angle as the center of motion. There is, therefore, a call for unusual mobility of the scapula, and, consequently, for a very complicated muscle machinery. On the other hand, the great force displayed in the different motions of the upper extremity calls for great stability of the shoulder-blade. Since the only bony connection of the scapula is a syndesmosis with the clavicle, one may readily see that the task of stabilizing the shoulder-blade as well as of moving it in all possible directions falls upon the muscular apparatus. The latter, therefore, is exceedingly complicated and voluminous.

The rotatory motion is carried out by the trapezius and serratus magnus. Both muscles are turning the scapula in the same direction, approaching the upper border of the bone nearer to the median line. The serratus executes this rotation around the upper and outer angle of the scapula as the center, while the trapezius rotates around the upper inner angle. In contracting, the serratus also forces the scapula closely to the posterior thoracic wall, in this way acting as stabilizer of this bone, in support of the latissimus dorsi. If we consider that in right angle abduction the action of the deltoid muscle proper is completed and the humerus locked in this position against further abduction, by the scapulohumeral joint, by the tension of the lower portion of the capsule, and by the teres major muscle, it becomes clear why the rotatory motion of the scapula is so necessary to complete the elevation of the arm from the horizontal position to the perpendicular. It is also clear why this motion is so amply provided for by such powerful muscles as the trapezius, in its upper and middle fibers, and the serratus magnus. In the combined contracture, these muscles lock each other against the back and forward shifting of the scapula in which respect they are antagonists, and there remains only their synergistic component, which rotates the scapula.[1]

[1] Isolated paralysis of the trapezius muscle is very rarely observed in anterior poliomyelitis. But it occurs occasionally from peripheral lesions to the spinal accessory nerve following dissections of the neck. In these cases there exists a dropping as well as a forward displacement of the shoulder-blade.

The Winged Shoulder.—In the case of an isolated paralysis of the serratus magnus muscle, one may readily appreciate the handicap which exists in abduction motion of the arm. With the rotatory action of the serratus muscle eliminated, there is quite a preponderance of the antagonistic rotators of the scapula, which rotate in the opposite direction, namely, the rhomboid muscles and the levator anguli. They lower the upper outer scapular angle and, with it, the arm; they draw the lower angle and the vertebral border nearer to the midline. The paralysis of the serratus magnus produces a peculiar position of the scapula in relation to the thorax. This appears principally in the forward motion of the arm. When the arm is brought diagonally or straight forward, the scapula is seen to leave the thoracic wall with its vertebral border coming strongly into relief (winged shoulder). There is then a disability of the arm to be abducted laterally beyond the horizontal line, and sometimes abduction to the horizontal becomes difficult. There is a noticeable drooping of the acromion forward and downward while the inferior angle of the scapula projects into the back muscles when the arm is flexed forward in the sagittal plane. Sometimes the inferior angle of the scapula, which is usually covered by the upper border of latissimus dorsi, will slip out from under this muscle sheet (Skillern).

Regarding the treatment, fixation of the winged scapula by proper braces has been considered, and a simple apparatus consisting of two firm pads pressing against the shoulder-blades and united by steel bands in front, with counter pads over the acromioclavicular junction and heavy shoulder straps to hold the shoulder-blade down, has been described by Neumeister. However, most of the favorable reports have been obtained in the operative treatment. Eiselsberg (1898) was the first to attempt operation in winged scapula. He operated on two patients, his procedure consisting in suturing together the two vertebral borders of the shoulder-blades in the midline. As this did not give satisfactory results, the superior inner angle was also united in a second step and the final results were reported to be good. It is easy to be seen that this method severely handicaps the free mobility of the shoulder-blade and that it is open to grave objections. In 1903, Duval reported an operation in which he sutured the vertebral border of the bone to the adjacent ribs. He tried to avoid the inhibition of abduction incidental to the fixation of the scapula by slanting off the inner border downward and outward in the direction in which the combined trapezius and serratus action would turn it, so that an elevation of the acromion would result. He makes an incision over the vertebral border with the bone in normal position. The incision reaches from the root of the spine of the scapula downward to the inferior angle. A vertical incision of the trapezius and rhomboid along the spinal border is made and the latissimus dorsi is retracted downward. At the internal surface of the scapula, the periosteum is incised near the border and deflected together with the serratus magnus, and this periosteum-muscle

flap is resected. This is done to prevent interposition of a soft tissue flap between the places of fixation. Then the periosteum is stripped off from the sixth and seventh ribs at some distance from the midline, and two silver wires are passed around the ribs and through the drill holes in the scapula and tied, fixing the scapula to the ribs. Finally, the trapezius and rhomboid muscles are re-sutured to the scapula and the wound is closed.

Skillern reports a case in which an inoculation of a healthy nerve into the distal end of the injured long thoracic nerve was made in a case of serratus paralysis. The short subscapular nerve was used for this purpose. The nerve is reached from a horseshoe flap incision over the hollow of the axilla in front, with the base corresponding to the anterior fold or lower border of the pectoralis major; this flap, including the underlying axillary fascia, is raised and reflected over the anterior wall. Then the long thoracic nerve is dissected along the middle of the inner wall of the axilla and beneath the fascia covering the serratus magnus. It is then traced upward to the apex of the axilla beneath the great neurovascular bundle which is retracted forward. Then the three subscapular nerves are readily seen underneath the fascia resting upon the subscapularis muscle and are traced to the posterior cord. The uppermost of the three is now found one-half inch from the long thoracic nerve. It is approximated, both nerves severed, and the proximal end of the subscapular nerve is united end to end with the distal end of the long thoracic nerve. The line of suture is wrapped with egg membrane. No end results of this method have been reported.

Case Reports.—E. K., 18 years. Complains of deficiency in the right shoulder for the last 6 years which had greatly increased until it reached a stationary point 2 years ago. The difficulty consisted in raising the arm above the horizontal line. This was impossible unless done by swinging motion. When this was done, the shoulder-blade seemed to rotate about the vertical axis so that its median border became separated from the ribs and came strongly into relief. There was paralysis of the serratus magnus muscle, the cause of which could not be determined.

E. T., 8 years. This patient had an attack of infantile paralysis 2 years ago which involved his left shoulder. He was able to elevate his arm up to the horizontal, but it was difficult to go beyond. When elevating his arm, especially in a forward plane, the scapula was seen to rotate about a vertical axis, the inner border leaving the contact with the thorax (Plate IV, 1).

Neither of the two cases was treated, because there was no functional deficiency extensive enough to warrant an operative procedure.

SCAPULOHUMERAL MUSCLES

Deltoid Paralysis.—Of the deficiencies caused by paralysis of the scapulohumeral group of muscles, the one due to paralysis of the deltoid is by far the most prominent both in frequency and in degree of its disabling effect. The question why paralysis of any one muscle should be fraught with such grave consequences to the function of the joint as is the deltoid paralysis is readily answered from considerations arising out of the knowledge of the physiology and dynamics of this muscle.

The deltoid is practically the only abductor of the arm capable of doing any substantial amount of work. It arises from the outer side of the clavicle, the free border of the acromion, and the lower lip of the spine of the scapula. It is inserted into the middle of the outer side of the humerus, its widespread fibers converging into a strong and narrow tendon of insertion attached to the deltoid tuberosity of the humerus. This muscle consists of three portions with more or less distinct individual function. The middle portion is a direct outward elevator; the anterior and posterior portions abduct the arm as well as carry it forward or backward, respectively. In this work, the muscle is assisted by the supraspinatus muscle coming from the supraspinous portion of the scapula, which is inserted into the highest facet of the greater tuberosity of the humerus. This latter muscle is adherent to the capsule, preventing plication of its upper portion which might constitute an impediment in the act of abduction.

It is the function of the deltoid muscle to elevate the arm up to an angle which differs in the various planes of abduction. In forward abduction, it carries the arm up to a height of about 130°; in abduction in the frontal plane, its range is up to 90°, or the horizontal; while in abduction in an oblique posterior plane, its elevating power is about 45°. Further elevation beyond the ranges mentioned is checked, besides, by the overhanging edge of the acromion, the lower portion of the capsule and, in the anterior planes of abduction, also by the tension of the teres major.

Abduction of the arm beyond the ranges of the deltoid is taken care of by rotation of the shoulder-blade, as has been stated before. In this work the trapezius muscle plays the most prominent part. Its action begins when that of the deltoid ends or is checked by contact of the humerus with the acromion and by capsular and muscular tension.

But the loss of function of the deltoid results in inability to elevate up to the point where the trapezius and other scapulothoracic mucles begin their work of abduction. The greater majority of cases of deltoid paralysis are cases of anterior poliomyelitis, the paralyses, as a rule, being associated with flaccid paralysis of other muscles of the body.

In the writer's series of 883 cases of infantile paralysis, 70 cases involved the upper extremity, or 8 per cent. Of the 70 cases involving

the upper extremity, not less than 56 cases involved the shoulder joint either alone or in conjunction with other joints. All the shoulder joints involved, except one (serratus paralysis) had a paralyzed deltoid muscle. The first question which offers itself is, whether or not the paralysis of the deltoid, found after the attack of anterior poliomyelitis, is a permanent or a temporary one; whether the second, if permanent, entails an absolute inability to abduct the arm?

The first question may be answered best by referring to the statistics of Lovett, which show that permanent and complete paralysis of muscles in infantile paralysis are by far in the minority as compared with temporary and partial paralysis, the ratio being 1 to 6. This fact carries very considerable weight in regard to our attitude of treatment of paralysis of the deltoid muscle in the earlier stages of anterior poliomyelitis. If the chances of spontaneous recovery are as favorable as the statistics show, it follows that the most serious consideration must be given to the conservative treatment which will guarantee the best possible preservation of latent muscle power and the most favorable muscle development under a proper reëducational management. Out of the series of 56 cases of deltoid paralysis, 16 were classified as more or less recent cases. By this is meant that the cases ranged anywhere from 8 weeks to 2 years after the onset of paralysis. It seems perfectly proper to qualify a case as a recent case within this period of time from the viewpoint of the advisability of conservative treatment; some cases will seem to be doubtful as to whether the paralysis is a permanent one or not after a period of 2 years. Other cases will show such changes of atrophy, shrinkage, etc., after a much shorter period of time that there can be little doubt as to the fact that the muscle is irretrievably lost. Of these 16 cases in the series, 4 were not treated and 12 were treated.

Of the 12 conservatively treated cases, a complete recovery of the deltoid muscle was obtained in 3, and a decided improvement in the power of this muscle was obtained in 4 cases, making a total of 7 cases recovered or markedly improved. A noticeable recovery of the deltoid muscle was noticed in one case as late as 2 years after the onset of the paralysis, although 1 year had passed between the onset of the disease and the beginning of the proper treatment. In another instance, the treatment began 6 weeks after the onset of the paralysis, the patient recovering the use of the lost deltoid muscle almost entirely, being able to elevate actively to 90° and to hold the arm abducted. In other cases, a recovery was noted after an interval of 2 or 3 months had passed between the onset of the disease and the beginning of the treatment.

Conservative Treatment—Attitudes of Rest.—For the deltoid muscle, the attitude of rest is that of abduction of 90° with the scapula rotated backward. It is best to maintain this position by means of a so-called aëroplane splint which allows abduction of the arm at 90° and outward rotation and also holds the elbow in a position of right angle flexion

and the forearm in a position midway between pronation and supination. This position is preferable to the one obtained by what is called a platform splint in which the arm is also abducted to 90°, but the forearm is allowed to rest horizontally upon the extremity of the splint with the forearm pronated. The first-named position takes care of the outward rotation of the humerus, thereby relaxing the infraspinatus muscle and the teres minor, and preventing such contractions of the rotators as might occur on the part of the subscapularis muscle, the latissimus dorsi, and the teres major. It is necessary for the patient to maintain this position without interruption, and the splint must never be removed except for treatment and then only with special precautions. The patient must lie down with his arm held abducted so that the deltoid muscle may always be relaxed.

Muscle Educational Treatment.—In regard to this treatment which must accompany the treatment of rest, it is well to keep in mind the points given in the excellent book of Bowen and McKenzie. Whatever active motion is instituted must begin near the position of rest and from there work gradually to the more remote positions of the arm; that is to say, the attempt at motion of the deltoid should first be carried out with the arm abducted and only as the power increases may abduction be allowed to follow gradually. With these precautions, one is often surprised to see remarkable results in a very short time. The first attempt of active motion of the deltoid must naturally be carried out in the recumbent position. It is not uncommon to detect slight power in this muscle when the patient is lying down, whereas it seems to be entirely absent when the patient is sitting up with the arm hanging by the side. In fact, no deltoid muscle should be declared completely paralyzed from a failure to carry out abduction so long as the patient is in the sitting or upright position. In order to elicit the feeble action of the deltoid, which is very often present, it is indispensable to have the patient prone or supine on the table.

Substitutionary Motion.—In the event that the deltoid muscle fails to present any signs of activity or life, in the event of no functional or electrodiagnostic response, in the event of degeneration of the muscle with atrophy and subluxation of the head of the humerus, the recovery of this muscle and its reëducation to functional ability is beyond hope.

Before a surgical operation to supplant the lost deltoid is contemplated, it is necessary to establish the fact whether or not abduction of the arm is possible to a sufficient degree in spite of the absence of deltoid action; if abduction of the arm could be procured without the deltoid, the disability would not be absolute. This leads us to a study of substitutionary motion in deltoid paralysis and to the analysis of the different mechanisms applied. The patient may force the arm away from the body, in an attempt of abduction, by a side and forward swing of the body which starts with a contracture of the coracobrachialis muscle. This latter effects a forward swing of the arm which may be

carried out with sufficient force to throw the forearm into flexion until, in acute flexion, it is balanced against gravity, bringing the hand near the face; a substitutionary motion which serves the paralyzed deltoid as well as the flail elbow. Almost without exception, this substitute is laborious, unsightly, and only of lesser practical value to the patient.

Another mechanism of substitutionary motion in deltoid paralysis is based upon the stabilization of the shoulder joint. According to Poirier, the great stabilizer of the shoulder joint is the triceps muscle. Although the long portion of this muscle contributes only feebly to the extension action of the elbow, its main function is that of maintaining the head of the humerus firmly within the glenoid fossa. The stabilization may be carried out in two ways: either by active contraction of the triceps muscle, extending the elbow; or by passive tension of the triceps muscle acutely flexing the elbow. We have seen patients use both of these methods. They are sometimes able to abduct the arm by contraction of the triceps and sometimes by acute flexion. In either event, the head of the humerus is pressed firmly against the glenoid cavity, making a mechanical unit, as it were, out of the humerus and scapula, which is then moved by the trapezius muscle. It is evident that such action cannot carry with it any great force and that the best the patients can do is to elevate the arm to about 30° or at most 45° from the body with comparatively little gravitative stress at this angle. I have never seen any greater amount of abduction being accomplished by this mechanism unless the patient is in a recumbent position. This sort of substitutionary motion naturally presupposes a good function of the triceps as well as the flexors of the elbow, but these muscles quite often are also involved in the paralysis.

After all, these substitutionary motions offer, even with the greatest skill on the part of the patient, only a slight and insufficient substitute for a lost action of the deltoid. When compared with the operative result which will be shown later, the functional advantage derived from such substitutionary motion is rather limited.

Operative Treatment.—Permanent inability of abduction and failure to replace the deltoid action by substitutionary motion to a degree of satisfaction constitute the indication for operative methods. Generally speaking, two ways are open: first, tendon transplantation; second, fixation (arthrodesis) of the shoulder joint.

Tendon Transplantation.—It has been mentioned that deltoid paralysis is hardly ever strictly isolated. The table on page 43 gives a review of the extent of paralysis in the writer's series.

The proximity of abundant muscle material has invited a number of methods of muscle transposition and transplantation. One of the earliest is a method of Winiwarter who used the clavicular fibers of the pectoralis major as the substituting muscle. Hoffa used the trapezius and pectoralis major for implantation upon the paralyzed deltoid and was able to report some favorable results. Hildebrandt likewise made use of the pectoralis major to supplant the paralyzed deltoid. His

technic consisted of an incision upward from the junction of the fourth rib and the sternum to the sternoclavicular joint and from there at right angle outward along the upper border of the clavicle, reaching as far as the acromion. He then effected a separation of this sterno-clavicular portion of the pectoralis major, being very careful not to injure the anterior thoracic nerves. This gave him a free flap of the pectoralis major which was turned over and fastened to the lateral third of the clavicle and the acromion. By this operation, he was able to produce active elevation of the arm forward to the horizontal. The preservation of the thoracic nerves and vessels reaching the pectoralis major from the under side is an absolute essential for the success of the operation. It is also a factor which makes for considerable technical difficulties. Possibly it was on account of the latter fact that the methods of muscle transplantation never gained general acceptance. It can also be seen that the results were by no means uniform and none of the methods has been developed to a degree where it would offer a reliable average of functional results.

	Unilateral	Bilateral	Total
Deltoid and supraspinatus	12	5	17
Deltoid and trapezius	1		1
Deltoid and wrist and fingers	2		2
Deltoid and flexors of the elbow	10		10
Deltoid and flexors and extensors of the elbow	9	1	10
Deltoid and flexors and extensors of the elbow and hand	10		10
Deltoid and flexors of the elbow and muscles of the thumb	3		3
Deltoid and extensors of the elbow and extensors of the wrist	1	1	2
Deltoid and extensors of the wrist	1		1
Deltoid and extensors of the wrist and flexors of the wrist	1		1
			57

Shoulder-joint Fixation.—The fixation of the paralytic shoulder by means of silk ligaments is a method advocated by Bartow and Plummer (1913). The technic as given by these authors is as follows:

An incision one inch long is made on the top of the acromion one-half inch from its end. This incision extends down to the bone and runs along the line between the insertion of the trapezius and the deltoid muscle. Then a suitable drill having an eye at its point is entered on top of the acromion one-half inch from its tip and is pushed downward through the bone into the shoulder joint. The drill is next

made to engage into the head of the humerus on its external aspect and near the anatomical neck. It is then pushed through the head of the humerus and the greater tuberosity to the base of the latter, emerging on its surface external to the bicipital groove. The drill is then carried through the deltoid muscle to the skin where a short incision is made. Both ends of a piece of fine, bronze wire are threaded into the drill eye and, on withdrawing the drill, the wire is pulled through the bones, its loop and ends protruding. Then the drill is again inserted into the acromion, this time three-fourths of an inch back of the first puncture, and a similar parallel tunnel is made, the drill emerging three-fourths of an inch backward from the first tunnel on the posterior aspect of the greater tuberosity. Where the drills have penetrated the deltoid, a loop of wire is passed under that muscle from puncture to puncture. Then a double strand of No. 14 or 16 paraffin Lange silk is attached to the wire loop and pulled through this outer tunnel. The distal end is then dropped into the loop of wire, passed under the deltoid and pulled through to the opposite incision. Lastly, the silk is pulled through the posterior tunnel, and finally the strands are tied on top of the acromion, while the head of the humerus is being slightly abducted.

The operation is technically not difficult and the cases reported by Bartow and Plummer were successful and a considerable amount of abduction was obtained. In a measure, the method may be considered as a partial arthrodesis. Late end results are not reported.

But the only method which may be relied upon to give permanent results is the arthrodesis of the shoulder joint. Even Lorenz, who generally condemns arthrodesis, is an advocate of it in the treatment of the flail shoulder. The first arthrodesis was performed by Albert (1879). Bradford, Whitman, and, above all, Robert Jones, are advocates of the arthrodesis. Vulpius in 1912 reported 12 cases of flail shoulder treated by arthrodesis, in which he exposed the head of the humerus from an anterior longitudinal incision, and then proceeded to the denudation of the head and the glenoid fossa. Silver wires finally secured the position between humerus and glenoid fossa which was one of abduction, slight forward flexion, and inward rotation. The average amount of forward flexion was 75°, the average amount of straight lateral abduction 60°, and the average amount of lateral backward extension was 30°.

Before entering into the details of the operation, the proper age for performing it is to be considered. Some authors, among them Lange, maintain that one should wait until the fourteenth or eighteenth year in arthrodesis of the shoulder for reasons of growth, following the general rule which applies to other large joints of the body. This we think is wholly unnecessary. If one considers that the problem of permanently dealing with the flail shoulder sometimes arises in very young children, the loss of eight or ten years in waiting must have a considerable influence upon the development of the extremity. It must be

remembered that during all this time the flailness of the shoulder is a grave obstacle to the functional development of the entire arm. Even if elbow and hand are in good condition, the total inability of abducting the arm from the body makes it impossible to give any educational training to the hand and forearm. Jones advocates the arthrodesis as early as six or eight years of age. It is true that when done at that age a greater amount of bone must be removed from the articular ends of the bones, in order to procure ankylosis; but this loss is outweighed by the advantage of early functional development of the extremity. It is still a question whether or not it is necessary to have complete bony fusion in order to obtain satisfactory function. It is, of course, by far the more desirable kind but we believe that a degree of fibrous ankylosis in smaller children is acceptable. As will be shown in our series later on, such fibrous ankylosis in younger children gives good functional results, which compare not unfavorably with the ankylosis produced in older children and in adults.

Lastly, one must decide at what angle the fusion should be accomplished and what the position should be in which the arm is held in the plaster-of-Paris cast following the operation. Lange proposes 60°; Vulpius the right-angle position; Vacchelli, who recently reported a series of cases ranging from five years to fifteen years, also fixes the arm at right angle with the body. It has been the custom of the writer to adopt a right-angle abduction as it seems to be the safer procedure and as one is apt to lose some of the abduction later on during the first few weeks of plaster fixation. Especially is this true in younger children where bony ankylosis cannot so thoroughly be relied upon.

Technic of the Operation.—The position of the patient is that of lying upon the sound side with the shoulder supported by sandbags. During the operation, it is necessary to exert a downward pull upon the shoulder. This is taken care of by one of the assistants standing on the side opposite the operator. The incision is made from the spine of the scapula forward, circling the acromion, and ending anteriorly over the coracoid process. After severing the skin and fat, the tissues are thoroughly liberated and turned upward in a semicircular flap. The liberation of this flap should be high enough to expose the edge of the acromion for a distance of one to one and a half inches upward. One then proceeds bluntly to divide the fibers of the deltoid muscle anteriorly and posteriorly at places corresponding to the edges of the middle portion. This separation is carried upward directly to the acromion and downward to the insertion of the deltoid muscle. In many cases, there is nothing left of the deltoid but a fibrous sheet while in others, there may be an amount of muscle material present. One then inserts a grooved director under the muscle, freeing the edges thoroughly until the instrument plays freely from the deltoid insertion upward to the acromial attachment of the middle portion. The acromion is now incised transversely three-fourths to one and a fourth inches from its edge and the bone is here cut through with an osteo-

tome. One now has a flap consisting of the middle portion of the deltoid muscle to which is attached the severed end of the acromion. This bone-muscle flap is turned downward. As this is done, the entire anterior surface of the shoulder joint capsule comes into view. This is opened by a longitudinal incision to which are added two short transverse incisions at the acromial end in order to procure better access to the glenoid cavity. The edges of the capsule are carefully secured by forceps and are widely retracted. Now, as the assistant pulls the arm downward, the glenoid fossa is seen in its entity and also most of the head of the humerus is visible. The long tendon of the biceps can be seen just in front of the incision of the capsule passing through the joint. The next step is the denudation of all cartilage covering the joint. First the cartilage covering the glenoid fossa is completely removed. One then proceeds to the removal of cartilage from the head of the humerus and to this end the head may be pushed through the incision in the capsule. One should see that the two articulating surfaces now fit into each other in the position of abduction. The next step is the insertion of chromic gut (No. 3 or 4), into the bone. The head of the humerus is drilled and the opposing portion of the acromion, also, and the catgut is then passed through both drill holes. Two of these sets of drill holes are made; one anteriorly and one about one-half inch posteriorly to the first. The sutures now passed through both drill canals are for the moment left untied. The capsule is closed by suturing the longitudinal slit transversely. This at once reefs and tightens the anterior capsular wall. Then the drill-hole sutures are tied over the capsule with the arm held in abduction, a position which from now on must be maintained continuously by one of the assistants until the shoulder rests safely in the plaster cast. Then we usually fasten the bone muscle flap, consisting of deltoid and the attached piece of the acromion, to the spine of the scapula instead of back to its place; in this way, the flap can be made to serve as a posterior check which counteracts any tendency of the humerus toward posterior displacement. The wound is now closed in layers and a plaster cast is applied reaching from the shoulders to the hips and encircling both arm and forearm. The position is that of abduction in the shoulder, inward rotation of the arm, and flexion of the elbow. The cast is left in place from two to three months, the wound being taken care of through a window in the cast. At the end of this time, the cast is removed and a platform splint already at hand is immediately applied. From this time on, the mechanical after treatment begins. This after treatment consists of massage of the muscles of the shoulder, especially the trapezius, and also of massage of the arm and forearm, to promote their recovery after the prolonged fixation (Plate V, 1, 2, 3, 4).

Together with massage, the active exercises are begun at once. They must be carefully timed and during the first weeks must be carried out under the strictest supervision. The details of the muscle educational treatment will be discussed again in a later chapter. It may be

mentioned here briefly that active elevation is encouraged by systematic writing exercises on the blackboard and other educational movements of the shoulder. Not until one is sure that active elevation of the entire extremity is possible and that the arm can be held in abduction for some time is the angle of the splint changed. When the splint is first taken off for muscle educational treatment, the patient must be in a recumbent position and only later is he allowed to take his muscle exercises sitting or standing up. Even then the assistant must carefully support the elbow during exercises until sufficient muscle power has been gained. Only when active elevation is assured, and this may take anywhere from four to six weeks after the removal of the cast, can the arm be left elevated without further support. We now begin with the gradual lowering of the angle of the splint by bending it down from time to time until within about three months after the removal of the cast, or within five or six months after the operation, the arthrodesis is solid enough and the development of the shoulder muscles complete enough to allow the definite discarding of the splint. Under these precautions, we have not seen any relaxation of the ankylosis nor any diminishing of the power of abduction on the part of the patient.

A table follows which contains data on 17 cases operated by this method (Plates VI, 1-4; VII, 1-6; VIII, 1-7).

A combination method of both intra-articular suspension and muscle plasty is that given by Kiliani. He uses the long tendon of the biceps for fixation of the head in the glenoid cavity. In addition, he carries out a muscle plasty by supplanting the trapezius for the paralyzed deltoid. An incision is made nine inches in length over the anterior border of the deltoid. The capsule is exposed and severed horizontally at its insertion to the humerus, the incision reaching three-fourths over its circumference. The biceps tendon is not cut. Now the free upper border of the capsule is pulled down and sutured to the humerus at a line two and one half inches below, while the arm is held horizontally. Then the long tendon of the biceps is pulled forth through the sulcus intertubercularis, out of the capsule, and its surplus length is used to make a double loop which is sewed together. In this way, the biceps is made tight and, together with the tightened capsule, it draws the head of the humerus firmly against the glenoid cavity. He then proceeds to the muscle plasty. The deltoid is dissected entirely from the clavicle and the acromion, so that its upper border is free. Then the insertion of the trapezius is severed from its corresponding attachments at the clavicle and at the acromion. Lastly, the free edges of the two muscles are united by interrupted catgut sutures, thus making one muscle. He reports that he obtains a moderate active abduction. There is also a considerable cosmetic effect as the subluxation of the humerus is corrected and the shoulder assumes the full contour of a normal shoulder.

LEGEND FOR PLATE V

TECHNIC OF ARTHRODESIS

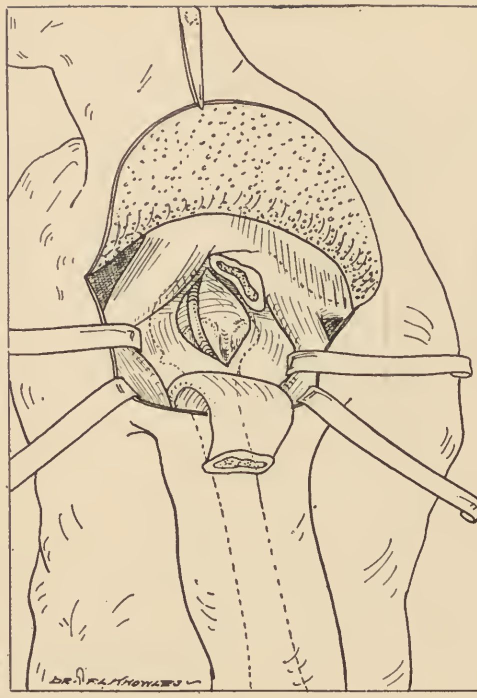
FIG. 1.—INCISION AND SKIN FLAP.

FIG. 2.—OSTEOTOMY OF ACROMION WITH DELTOID FLAP TURNED DOWN; CAPSULE OPENED, SHOWING TENDON OF LONG HEAD OF BICEPS.

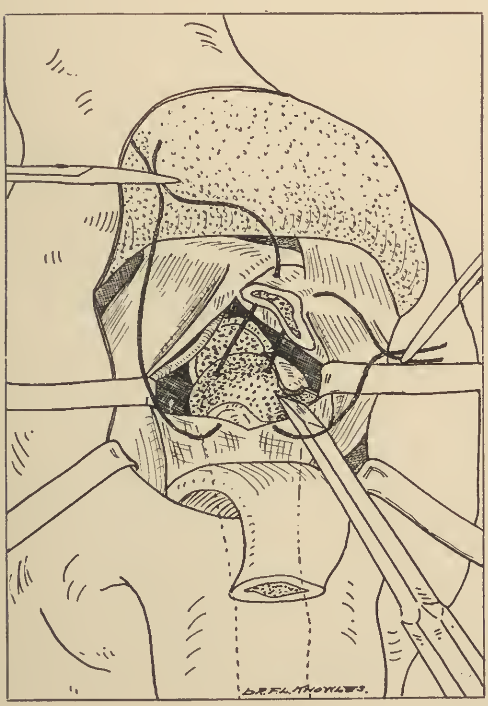
FIG 3.—THE PLACING OF WIRES THROUGH DENUDED HEAD AND BASE OF ACROMION.

FIG. 4.—TRANSVERSE SUTURE OF CAPSULE; WIRES TIED OVER IT.

1



2



3

4

LEGEND FOR PLATE VI

FIG. 1.—J. B. PARALYTIC FLAIL SHOULDER.

FIG. 2.—J. B. AFTER ARTHRODESIS OF SHOULDER.

FIG. 3.—H. S. PARALYTIC FLAIL SHOULDER AND WRIST.

FIG. 4.—H. S. AFTER ARTHRODESIS OF SHOULDER AND WRIST.

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LEGEND FOR PLATE VII

Fig. 1.—D. H. Paralytic Flail Right Shoulder.

Fig. 2.—T. S. Paralytic Flail Right Shoulder after Arthrodesis.

Fig. 3.—M. McG.—Paralytic Flail Shoulder, Wrist and Elbow.

Fig. 4.—M. McG. After Arthrodesis of Shoulder, Elbow Plasty, Arthrodesis of Wrist, and Interosseous Transplantation of Flexors.

Fig. 5.—M. C. Paralytic Flail Right Shoulder.

Fig. 6.—M. C. After Arthrodesis of Shoulder.

PLATE VII

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LEGEND FOR PLATE VIII

Fig. 1.—B. F. Paralytic Flail Left Shoulder, Elbow and Wrist.

Fig. 2.—B. F. After Arthrodesis of Shoulder, Flexor Plasty of Elbow and Arthrodesis of Wrist.

Fig. 3.—B. R. Paralytic Flail Shoulder and Elbow; Thenar Palsy.

Figs. 4, 5.—B. R. Result of Thumb Plasty for Thenar Palsy.

Fig. 6.—B. R. Result of Plasty of Elbow.

Fig. 7.—B. R. Result of Arthrodesis of Shoulder and Plasty of Elbow.

PLATE VIII

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Name	Sex	Age	Duration	Since Operation	Side	Active Abduction	Result	Ankylosis	
J. B.	M	21	8	8 mo.	R	90	good	bony	1
H. S.	M	11	8	1 yr.	L	120	good	bony	2
H. F.	F	12	6	6 mo.	R	70	good	?	3
I. S.	F	27	8	10 mo.	R	90	good	bony	4
G. O.	F	24	17	2 mo.	R	?	undet.	undet.	5
H.	F	15	8	2 mo.	R	?	undet.	undet.	6
I. H.	M	10	. .	3 mo.	L	?	?	?	7
T. O	M	14	11	8 mo.	R	100	good	bony	8
L. B.	M	16	10	1 yr.	L	85	good	bony	9
B. F.	F	12	9	1 yr.	L	65	good	fibr.	10
H. T.	F	11	2	10 mo.	L	100	good	bony	11
E. B.	F	9	2	3 yr.	R	60	fair	fibr.	12
B. R.	F	14	9	1 yr.	R	100	good	bony	13
V. M.	F	13	. .	$1\frac{1}{2}$ yr.	L	50	fair	fibr.	14
B. R.	F	20	1	6 mo.	L	45	poor	fibr.	15
M. Mc.	M	8	4	6 mo.	L	100	good	bony	16
M. C.	M	15	12	1 yr.	L	45	poor	fibr.	17

Degree of Abduction

good	120–1 100–4 90–2 85–1 70–1 65–1	10
fair	60–1 50–1	2
poor	45–2	2

Total 14

Type of Ankylosis

bony	8
fibr.	5
undet.	4
	—
	17

THE FLAIL ELBOW

The Interrelation between Shoulder and Elbow Movement.—What the ability of lifting the arm means to the function of the shoulder joint has been the subject of discussion in the previous chapter. Since this ability offers distinct advantages to the use of the elbow joint also, a few words may be in order regarding the functional relationship of these two joints. The removal of the elbow from the body side at once increases the sweep of motion for the forearm, the hand and the fingers. The weight of the extremity, in the position of abduction, is borne largely from the shoulder joint. The forces of gravity interfere very little with the principal motion of the elbow, namely,

flexion and extension, and, also, pronation and supination, the strain of gravity being considerably lessened when the elbow is elevated. Under these mechanical advantages, the substitutionary motions which have been mentioned before come much more into their own, when, otherwise, they could not carry out their feeble functions against the odds of gravitative strain. Of the substitutional motions, the flexion of the elbow by the muscles of the forearm and the supination of the forearm by the extensors of the elbow may be mentioned.

Muscle Dynamics of the Elbow.—The flexors of the elbow of the first order are: first, the biceps, which is a pure flexor when the forearm is held in supination; with the forearm in pronation, it is a secondary flexor, the flexor action becoming effective only after supination has been completed. Second in importance as flexor of the elbow is the brachialis anticus. It is a more energetic flexor, displaying more power. Its fibers are short and numerous. The arrangement of the insertion of these muscles explains the corelationship existing between them. The biceps, having its insertion at a considerable distance from the axis of the joint, covers, per space unit of contraction, a shorter angular distance of the forearm, but represents a larger momentum of force. The brachialis anticus, having its insertion close to the center of motion, covers a greater angular distance of the forearm per unit of contraction but represents a lesser momentum of force. These muscles have the same corelationship to each other which is found in the action of biceps and inner hamstrings at the knee.

The supinator longus is essentially a flexor of the elbow. In contraction, it maintains for the forearm a position midway between pronation and supination. Flexors of the elbow of the second order, or auxiliary flexors, are: first, the pronator teres; up to full pronation, it acts as a flexor upon the elbow joint, but in extreme pronation again the flexor action of this muscle is practically nil; therefore, in order to bring out this flexor action, a midway position between pronation and supination must be chosen, such as the action of the supinator longus would represent. There is, therefore, in a sense, a certain synergism between the supinator longus and the pronator teres. In the same sense, there is also a synergism between the supinator longus and the biceps, since the former maintains the forearm in a position favorable to flexion action midway between pronation and supination, so that the biceps does not spend itself in supination and can therefore assert its flexion component.

Another auxiliary flexor of the elbow is the flexor carpi radialis. This muscle which is primarily a flexor of the wrist becomes an auxiliary flexor of the elbow as well as a pronator of the forearm when acting from a position of supination of the forearm and extension of the wrist.

The palmaris longus is primarily a flexor of the wrist and, secondarily, to a very slight extent, a flexor of the elbow.

A glance at the conditions of the origin of these muscles at the

elbow will show that this auxiliary flexor action can only be a very feeble one and that it can exert itself at all only when these muscles are at their physiological optimum, that is, a position midway between flexion and extension or a position of semiextension. But under certain conditions, this secondary action of these muscles, although seemingly very insignificant, may be utilized so that they may act as substitutionary flexors of the elbow when the primary flexors of this joint are unavailable.

Pronation.—Pronators of the first order are:

The Pronator Teres.—This muscle arises from the internal condyle of the humerus, and, by its deep head, from the lateral side of the coronoid process of the ulna. It is inserted into the middle third of the outer border of the radius.

The Pronator Quadratus.—This muscle arises from the lower fourth of the outer side of the ulna and runs transversely into the lower fourth of the anterior surface of the radius. It produces pure pronation and it is at its physiological optimum when the forearm is in extreme supination.

As auxiliary pronators act: first, the flexor carpi radialis, the action of which muscle has already been considered. There is also the supinator longus which maintains the forearm in mid position between pronation and supination. A further auxiliary pronator is the flexor carpi ulnaris, primarily a flexor of the wrist with a secondary action of pronation of the forearm and flexion of the elbow. Its pronation component is still weaker than its flexion component on the elbow but may become more prominent under certain conditions.

Supination.—A supinator of the first order is the biceps. When the forearm is in pronation, this muscle is primarily a supinator and then a flexor of the elbow. When the forearm is in supination, the muscle is primarily a flexor of the elbow. The supinator brevis collaborates with the biceps in the flexion of the elbow because it maintains the elbow in the supinated position in which the flexor action of the biceps becomes more effective. The *supinator brevis* arises from the external condyle of the humerus and from the lateral surface of the ulna and inserts into the outer border of the upper half of the radius immediately above the insertion of the pronator teres. This muscle is a true supinator in the same way as the pronator teres is a true pronator. A glance at the arrangement of pronators and supinators of the forearm reveals a peculiar situation. Both pronation and supination are represented by two muscles, one a long muscle (pronator teres and biceps) and one a short one (pronator quadratus and supinator brevis). The long muscles combine with their pronatory and supinatory action that of the flexion of the elbow. The meaning of this arrangement becomes clear if one considers that pronation and supination is a movement which must be carried out at any point of flexion or extension of the elbow. Just as much as the supination of the forearm is favorable for the flexion of the elbow, so the flexed position of

the elbow is most favorable for the action of the supinator brevis. In this position, the biceps is already in a state of contraction, and its potential power as supinator is much lessened. It is, therefore, in this situation of flexion that the coöperation of the supinator brevis is especially advantageous. On the other hand, let us suppose that the arm is held in flexion and the necessity of pronating arises. The pronator teres will be found similarly shortened, as the biceps was in the former instance, and its potential power as pronator is similarly diminished. It is, therefore, in this position of flexion of the elbow that the smaller muscles, namely, supinator brevis and pronator quadratus, come into the foreground in carrying out their respective functions of pronation and supination.

This system of double muscle arrangement to carry out the same motion in the joint can be followed through the different joints of the body where action in two or three planes is centered in one joint, though one will hardly find it as beautifully demonstrated anywhere else as it is in the muscle arrangement of the elbow.

The substitutionary motions for pronation and supination are not exhausted with the mechanisms just described. Rotation in the shoulder joint itself is also a factor in substituting pronation and supination. This motion is carried out by the inward and outward rotators of the shoulder joint. As auxiliary supinators, there should also be mentioned the extensors of the thumb, namely, the extensors pollicis longus and brevis.

The writer's series of elbow paralysis embraces 42 cases. Distribution of the paralysis:

	Cases
Flail elbow alone	2
Flail elbow plus flail shoulder	18
Flail elbow plus paralysis of the hand	1
Flail elbow plus paralysis of the hand and wrist, plus flail shoulder	21
Total	42

The distribution of the elbow paralysis was as follows:

		Cases
Biceps, partial paralysis	15	
Total paralysis	24	
Total		39
Triceps: Partial	15	
Total	17	
Total		32
Brachialis Anticus:		
Partial paralysis	14	
Total	21	
Total		35

Treatment.—The conservative treatment of the flail elbow follows the principles indicated in the discussion of the conservative treatment of the flail shoulder. Relaxation of the muscles involved is the first requisite. This can be done only by appropriate and constant splinting. When combined with paralysis of the shoulder, the splinting of the elbow is done most advantageously by a platform splint which not only provides for abduction position in the shoulder, but also for flexion in the elbow, and, for the forearm, a position midway between pronation and supination.

The problem of operative treatment of the flail elbow offers many difficulties. There is no muscle material at hand to serve for tendon transplantation. Arthrodesis of the elbow, on the other hand, is difficult, and very doubtful in younger individuals, and there seems to be no reliable method which could be applied to the juvenile and adolescent patient.

Bartow and Plummer's silk ligament suspension method has been applied to the elbow. It has the same disadvantage, already mentioned for the shoulder, that it does not seem to accomplish a lasting fixation. Robert Jones advises the resection of a diamond-shaped piece of skin from the fold of the elbow and suturing of the edges in transverse direction. This procedure holds the elbow in a suitable position of flexion.

For a number of years, the writer has attempted to cope with the situation by applying a method of muscle transposition which makes use of the auxiliary flexors of the elbow, namely, the flexors of the wrist and fingers. In order to increase the effectiveness of these muscles upon the elbow joint, a method of transposition was devised whereby their point of origin is carried upward to a point mechanically more favorable for the leverage of these muscles upon the elbow joint. The technic is as follows: An incision is made on the inner side of the humerus beginning three inches above the internal epicondyle between brachialis anticus and triceps muscles. This incision is carried down to the internal condyle and from there, in an obliquely downward and outward direction, over the anterior aspect of the forearm. After dissection of fat and fascia, the ulnar nerve is first located behind the internal epicondyle and then drawn backward. Next, the insertion of the flexor muscles of the forearm at the internal epicondyle is carefully dissected and the muscles are stripped off the bone in one mass. This mass comprises the superficial head of the pronator teres, the flexor carpi radialis and the palmaris longus. One may go as far as an inch or an inch and a half from the internal condyle downward in the dissection of the origin of these muscles. At this point one must stop, because here the nerve supply from the median nerve enters these muscles from below. It is possible, however, to mobilize this muscle mass sufficiently so that a muscle flap can now be lifted up and transplanted upward two inches above the internal epicondyle into the intermuscular septum which divides the triceps muscle from the bra-

chialis anticus. In this dissection one should proceed with the greatest caution not only because of possible injury to the ulnar nerve, but also on account of the proximity of the brachial artery. The muscles having been safely anchored to the septum, the wound is now closed in layers and the arm is put up in flexion and in a position midway between pronation and supination. In some cases one may carry out a similar procedure on the outer side of the forearm using the supinator longus in the same way, and, by transplanting its origin higher up, increasing its leverage upon the elbow joint; but in as much as the supinator longus already acts as a flexor of the elbow joint, it will seldom be necessary to give it additional strength by transposing its point of origin.

The position of flexion should be maintained for at least two months, but the cast may be removed after two or three weeks to be immediately supplanted by an appropriate splint. The after treatment consists in active motion and massage carefully apportioned and constantly supervised so as to protect the muscles from strain and exhaustion. Under no circumstances must flexion of the elbow be allowed to decrease abruptly (Plate IX, 1, 2).

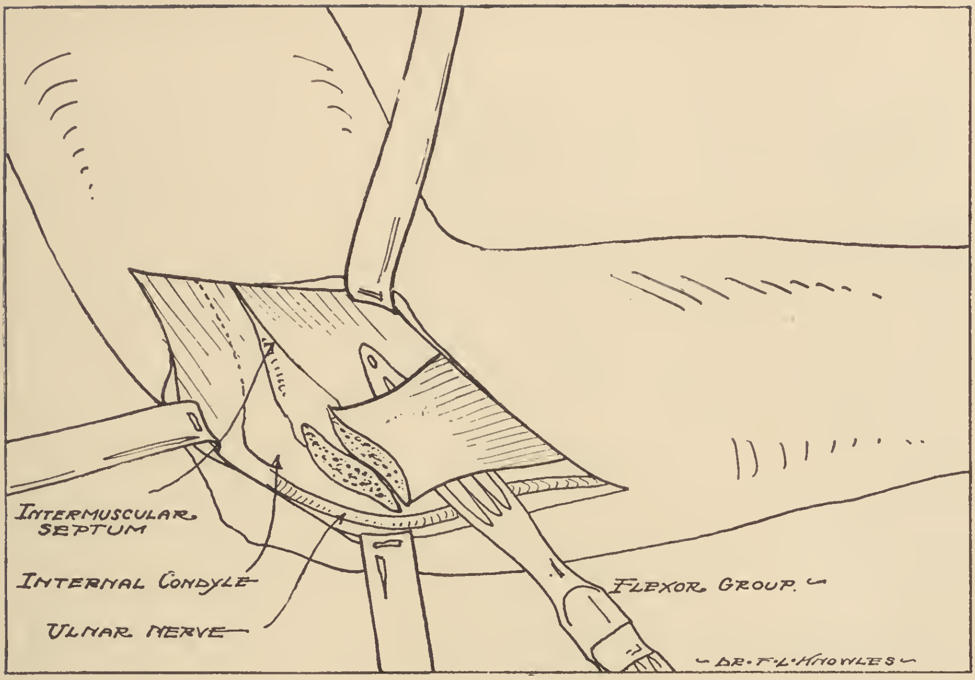
The one prerequisite which governs the indication of this operation is the integrity of the flexor muscles of the wrist and fingers. This is so stringent a condition that its neglect almost invariably leads to failure of the operative result. The flexor muscles of the forearm which are to be used as flexors of the elbow should not show any marked degree of paralysis or weakness if their transposition is to be accompanied by functional result. When these patients begin motion, it is noted very often that they can carry it out only with the fingers tightly closed and with the wrist hyperextended, in which position dynamic conditions are at their best regarding the forearm flexors. Even then one will notice that flexion of the elbow is very difficult at the beginning and requires considerable effort. As the muscles develop, however, the difficulty becomes less and in a majority of our cases we observed that a useful amount of active flexion of the elbow was attained. It is a matter of importance for the success of this secondary flexor action that the shoulder be capable of carrying out active abduction. With this, the elbow can be lifted to a horizontal position and the force of gravity will then not militate against the flexion power of the elbow. For this reason, the operation has proved most successful in cases in which there was either no paralysis of the shoulder or, as was true in the majority of cases, in which paralysis of the shoulder had previously or simultaneously been taken care of by arthrodesis. The operation of transposition of the forearm flexors was carried out in 15 cases (Plate X, 1-6; Plate XI, 1-6).

LEGEND FOR PLATE IX

TECHNIC OF ELBOW PLASTY

Fig. 1.—Stripping of Flexor Origin from Internal Condyle of Humerus.

Fig. 2.—Transposition Upward and Insertion to Supracondyloid Ridge.


INTERMUSCULAR SEPTUM
INTERNAL CONDYLE
ULNAR NERVE
FLEXOR GROUP.
DR. F. L. KNOWLES

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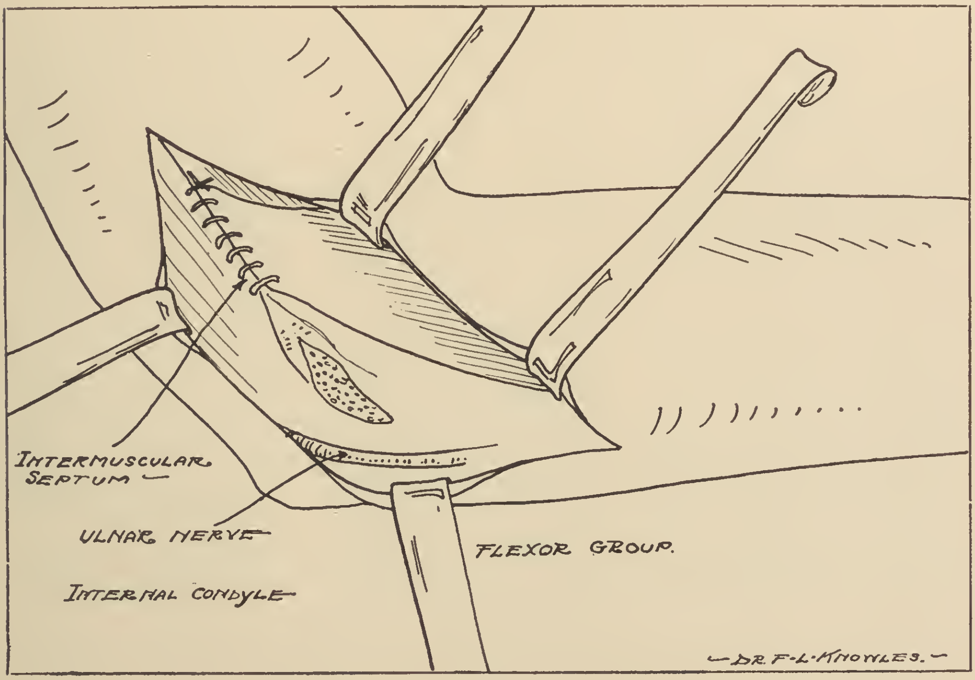
INTERMUSCULAR SEPTUM
ULNAR NERVE
FLEXOR GROUP.
INTERNAL CONDYLE
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2

LEGEND FOR PLATE X

Fig. 1.—L. B. Paralytic Flail Shoulder and Elbow; Result of Elbow Plasty.

Fig. 2.—L. B. Result of Arthrodesis of Shoulder, Elbow Plasty and Arthrodesis of Wrist.

Fig. 3.—V. M. Total Paralysis of Arm.

Fig. 4.—V. M. Result of Arthrodesis of Wrist.

Fig. 5.—V. M. Result of Arthrodesis of Shoulder, Muscle Plasty of Elbow and Arthrodesis of Wrist.

Fig. 6.—V. M. X-ray of Arthrodesis Shoulder Showing Fusion.

PLATE X

1

2

3

4

5

6

LEGEND FOR PLATE XI

FIG. 1.—I. T. PARALYTIC FLAIL SHOULDER AND ELBOW.

FIG. 2.—I. T. RESULT OF ELBOW PLASTY.

FIGS. 3, 4.—TECHNIC OF ELBOW PLASTY.

FIG. 5.—E. M. PARALYTIC FLAIL RIGHT SHOULDER AND ELBOW.

FIG. 6.—E. M. RESULT OF ELBOW PLASTY AND ARTHRODESIS OF SHOULDER.

1

2

3

4

5

6

Table of Operations for Flail Elbow (Flexor Plasty)

Case	Sex	Age	Time of Paralysis	Time Since Operation	Side	Technic	Function	Result	Remarks
A. T.	F	11	9 years	1 year	Left	Flexor plasty	Act. fl.	Good	Arthr. of shoulder
M. Mc	M	5	2	3 years	Right	do	No act. fl.	Poor	Reason of failure: extensive paralysis hand and wrist
B. F.	F	12	9	10 mos.	Left	do	Act. fl. F.	Fair	Arthr. of shoulder
L. H.	M	8	7	1 mo.	Right	do	Undeter'm	Und'd	Died 1 month after oper. of influenza.
S. S.	M	4	2	1 year	Left	do	Good	Good	
E. N.	F	9	2	1 year	Right	do	Good act. Fl.	Good	Arthr. of shoulder
D. B.	M	10	1	3 mos.	Left	do	Act. fair	Fair	Arthr. of shoulder refused
I. I.	F	8	4	2½ mos.	Right	do	Good act.	Good	Arthr. of shoulder refused
M. S.	F	7	5	6 mos.	Left	do	Good act.	Good	
B. R.	F	20	2	1 year	Left	do	F. poor	Poor	Arthr. of shoulder; cause of failure: par. hand and wrist
J. B.	M	21	13	6 mos.	Right	do	Act. good	Good	Arthr. of shoulder
B. R.	F	14	9	2 years	Right	do	Good	Good	
L. H.	M	6	5½	4 mos.	Right	do	No act. Fl.	Poor	Arthr. of shoulder; cause of failure: par. hand and wrist
T. G.	M	14	11	6 mos.	Right	do	Good act.	Good	Arthr. of shoulder
M. W.	F	6	1	1½ mos.	Right	do	Fair	Fair	

Summary of 15 F. P. of the Elbow

Results	
Good..........	8
Fair...........	3
Poor...........	3
Undecided......	1
Total........	15

Cause of failures: Paralysis of forearm flexors: 3 cases

Secondary flexor plasty established fair function of elbow.

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CHAPTER IV

THE PARALYTIC HAND

With the increased complexity of function, the muscle mechanical problems become more complicated and more difficult to handle. The analysis of the primitive motion of the hand must again precede the discussion of pathological conditions. The so-called primitive motions are in themselves complicated enough, but as the entire reconstruction work of the paralyzed hand is built up systematically upon the restitution of certain primitive movements both operatively and educationally, it is from this angle that we believe the problem is best approached.

The first of the primitive functions of the hand is the ability to close the fingers together and to relax them. A second is the forceps action of the thumb against the fingers, or of the fingers against the thumb. A third is the rotation of the hand in pronation and supination. A fourth is the flexion and extension movement of the wrist.

Turning our attention to the position of the wrist as the foundation for a subsequent play of the thumb and fingers, we shall start with the physiological postulate, so well emphasized by Robert Jones, that the proper position of the wrist for functional use is that of dorsiflexion. It is generally recognized that the grip of the finger is at best with the wrist in dorsiflexion and that, on the other hand, palmar flexion of the wrist diminishes the gripping power of the fingers. When the wrist is in hyperextension, the tone of the flexor muscles of the fingers is such that the greatest amount of power can be displayed per unit of contraction. As the wrist goes into position of flexion, the gripping power of the fingers greatly decreases owing to the loss of tension of the finger flexors. We have found experimentally that fully three-fourths of the potential contractile power of the fingers was exhausted by the time the wrist had moved from extension into full flexion. It is, therefore, necessary that a provision should be made to guarantee the hyperextension or dorsiflexion position for any hand, the function of which we aim to improve. It is equally essential that the wrist once placed in this position should be able to hold it rigidly. In other words, that there should be a firm stabilization of the wrist in this position of choice.

From this point of view, we may anticipate that the normal wrist must be endowed with powerful extensors, so arranged that they will hold the balance against the flexor force in exactly this position of hyperextension. We know that any muscle of the body exerts its functions in two components. One acting vertically upon the lever arm moves the joint; the other, parallel to the axis of the lever, stab-

ilizes the joint. The rotating component of the muscle and its stabilizing component always maintain a certain mathematical relationship which can be expressed by the sine of the angle between the longitudinal axis of the muscles and the longitudinal axis of the part moved, that is, the angle of insertion. In other words, the smaller this angle, the greater is the stabilizing and the smaller the rotating component of this muscle, and vice versa. Applying these considerations to the muscles attached to the wrist, we find them so arranged that there is a numerical as well as dynamic preponderance of the extensors of the wrist over the flexors. According to Frohse and Frankel, the respective dynamic values of the extensors of the wrist and of the flexors are as 2 to 1; that is, the sum total of the combined power of the extensors is twice as great as that of the flexors.

What is the meaning of this arrangement? Hyperextension means contraction of the extensors and passive tension of the flexors. Contraction decreases the potential power while, to a certain point, tension increases it. In this play between flexors and extensors of the wrist, there must be, then, a point in which the decreased potential power of the contracted extensors equals the increased power of the distended flexors, and at this point, there is complete equilibrium between the dynamic forces of the flexor muscles and the dynamic forces of the extensor muscles of the wrist. Owing to the preponderance of the extensors over the flexors, we must expect this point to be reached in a position of hyperextension of the wrist.

Theoretically, this hyperextension might, in a paralyzed hand, be procured in two ways. The one expedient is that of supplying the paralyzed or weakened extensors with necessary muscle power from the flexor group by means of tendon transference. In the case of a flail hand, the first question to be decided in this connection will be whether or not there is enough muscle material available for such transplantation; and, if available, if it will be sufficient not only to secure the desired position but also to maintain it with a considerable degree of stability? In the case of infantile paralysis of the hand, it may be said without restriction that the instances wherein such muscle material is available are extremely few and, therefore, that the problem of procuring the extensible wrist by muscle transplantation will usually collapse in itself for the lack of sufficient material.

The only other alternative is the stabilization of the wrist by arthrodesis. If the wrist is so stabilized, it is given a position which it will not only be able to maintain but maintain also against considerable resistance, and reliably enough to serve all practical purposes of finger motion. The only question arising is to what extent is the hand incapacitated by being unable to carry out flexion and extension motion as it would be in the case of arthodesis? Observation leads us to believe that the disability of the hand incurred by the loss of active flexion-extension power in the wrist is comparatively slight. With the exception of special occupations in which free wrist motion is essential, we

find that the arthrodesed wrist is suitable for most of the ordinary occupations in life especially if at least part of the pronation and supination power of the forearm is preserved.

A second elementary motion is that of closure of the fingers and their release. This motion depends first upon a free action in the metacarpophalangeal joints. Dorsal retraction of the fingers in this joint is a great obstacle, as it makes the contact between fingers and thumb very difficult. The balance between flexors and extensors of the fingers is so measured, however, that flexion of the wrist in itself is a factor contributory to hyperextension in the metacarpophalangeal joints by virtue of the passive tension brought about upon the extensor muscles of the fingers. It is one of the agencies of claw-hand formation seen in paralytic conditions as well as in ischemic and other contractures of the fingers. The loss of proper use of the finger flexors involves impairment of the intrinsic muscles of the hand, namely, the interossei and the lumbricales. These muscles are direct antagonists of the extensors of the fingers. Their primary function is the flexion of the metacarpophalangeal joint, and they also extend the mid and end phalangeal joints of the fingers. A hand deprived of the use of the lumbricales and interossei would find itself in a position of having to balance the extensors of the fingers against the long flexors of the fingers alone. But the long finger flexors, we know, have very little purchase upon the metacarpophalangeal joints. They flex the mid phalangeal joints (superficial flexors) and the end phalangeal joints (deep flexors). With these latter joints flexed, the action of the extensors will come principally upon the metacarpophalangeal joints forcing these into a position of hyperextension. So it becomes evident that the flexion of the wrist is, directly and indirectly, an important agency in bringing about this claw-hand contracture in the metacarpophalangeal joints.

But with the wrist in extension or hyperextension, the conditions are entirely different. The extensor tendons are relaxed and their strain upon the metacarpophalangeal joints is considerably lessened. On the other hand, the long flexors of the fingers being extended are in a state of increased tension and increased potential power, which gives them not only greater force of flexing the mid and end phalangeal joints, but procures also a much more advantageous condition for the action of interossei and lumbricales. In this manner we again find in the hyperextension position of the wrist an agency which counteracts the tendency of claw-hand formation, just as we could recognize in the hyperflexion of the wrist an agency favoring claw-hand contracture.

THE PREHENSILE FUNCTION OF THE HAND; THE APPROXIMATION OF THE FINGERS TO THE THUMB

Muscle Dynamics of the Thumb.—The action of the flexor pollicis longus is greatly influenced by the fact that there is a deflection of its tendon at the point of its contact with the trapezium. This latter bone projects into the course of the tendon acting as a fulcrum over which the tendon deflects obliquely outward until it reaches the end phalanx of the thumb. This arrangement greatly increases the power of this muscle. The short flexor muscles of the thumb dominate flexion of the first phalangeal joint; the long flexor of the thumb controls mainly the flexion of the end phalanx. This is an arrangement similar to that seen in the fingers, where the superficial flexors control flexion in the mid phalangeal joints, while the deep flexors control that of the end phalangeal joints. Between the action of the short and long flexors of the thumb and the extensors, there exists a peculiar relationship. If flexion of the basal phalanx is accompanied by flexion of end phalanx (long flexor action), then the carpometacarpal joint of the thumb goes into extension; if, however, flexion of the basal phalanx is accompanied by extension of the end phalanx, then the carpometacarpal joint goes into flexion (short flexor action). In the first case, the short flexor is checked by the extensors of the thumb and the motion is dominated by the long flexor; in the second case, the long flexor is checked by the long extensor of the thumb and motion is dominated by the short flexor and other thenar muscles. This fact is of prime importance for a substitutionary motion of opposing the thumb when the action of the opponens pollicis has been lost. In this case, the short flexors will flex the metacarpophalangeal joint; the end phalanx is held extended and the thumb crosses the palm.

In paralytic conditions, the instances in which opposition of the thumb to the fingers is lacking are quite numerous. The mechanism which normally opposes the thumb to the finger is rather a complicated one. Practically all muscles of the thenar take part in it, the short abductor of the thumb as well as the short flexor initiating the movement. Then the opponens of the thumb itself acts, and finally the motion is concluded by action of the adductor. Substitution for the lost opponens of the thumb, on the other hand, is rather difficult. It is possible for the patient to oppose the thumb by contraction of the adductor, so that objects may be held between thumb and index finger, but this movement is forced and laborious and only inadequately substitutes for the natural attitude of opposition. When the other muscles of the thenar are also involved, then we find the thumb placed hopelessly in a position of adduction in which it maintains the same plane with the palm of the hand and cannot, therefore, be used in the forceps action so essential for the play of the fingers. While this is a distinct

loss for the function of the hand, it may be met to a large measure by operative methods.

To a certain extent, the plastic methods of thumb reconstruction have advanced to a degree where considerable hope may be placed upon rebuilding this function by these methods. A proper space will be given to discussion and description of such methods.

In spastic paralysis one is often confronted with another disability arising from a flexion and opposition spasm. In these instances, motion of the thumb against the fingers and across the palm is carried out with such force and rapidity that in closing the fingers the thumb becomes caught under them. While there is no inability of opposition, the latter movement cannot properly be timed and coördinated, so that the tip of the thumb will not meet with the tip of the fingers. This also constitutes a considerable handicap for the function of the hand (see Chapter VI).

An instance of subtitutionary motion for the loss of interossei can be found in the action of the extensors of the fingers. These muscles are able to abduct the fingers from the midline, thereby substituting for the action of the dorsal interossei. When one examines a hand for ulnar paralysis, this point must be kept in mind. In this instance, the only true and reliable index will be the inability of the fifth finger to become abducted from the midline, since this motion is carried out by the abductor of the fifth finger entirely which is supplied by the ulnar nerve.

Flexion of the fingers can also be brought about passively by extension of the wrist. This mechanically stretches the flexor muscles and produces a passive pull upon the tendons of the long flexors of the fingers. In paralysis, this mechanism is widely used, and the patients who have no active power of the long flexors of the fingers will bring the wrist in the position of hyperextension in which the middle and end phalangeal joints will become flexed without any active contraction of the flexor muscles. On the other hand, substitutes can be used for extension of the fingers, as is seen often in cases of musculospiral paralysis. Here it is the acute flexion of the wrist which brings about the tension of the extensor tendons in a similar manner and this tension produces a passive extension of the fingers.

Finally, lateral motion of the fingers, which is a function of the interossei, can, in the case of the loss of these muscles, be brought about by the combined action of the extensors with the flexors of the finger. This motion is naturally much weaker than the original abductory and adductory action of the interossei. But it might on examination be confusing enough to misrepresent the true condition of the interossei. The loss of the interossei action can easily be detected if one causes the patient to attempt abduction of his fingers when the mid phalangeal joints are flexed. In this position, the extensor actions will not come into play, and abduction and adduction can be carried out by interossei only.

Among the 70 cases of infantile paralysis observed in the upper extremity, the distribution of the paralysis in the hand was as follows:

Distribution of Paralysis of the Hand in Poliomyelitis

	Cases
Involvement of hand and wrist	36
Involvement of hand alone	4
Involvement of hand and elbow	2
Involvement of hand and shoulder	3
Involvement of hand, shoulder and elbow	25
Total	70

Distribution of Paralysis by Muscle Groups

(*Investigation of 37 Cases*)

	Cases
Flexors of wrist and fingers	2
Extensors of wrist	1
Extensors of wrist and fingers	16
Extensors of wrist and fingers and thenar flexors	1
Thenar muscles	6
Extensors of wrist and fingers plus thenar muscles	1
Flexors of wrist and fingers plus extensors of fingers	3
Extensors of fingers plus flexors of wrist	1
Extensors of wrist and fingers plus flexors of wrist and fingers	4
Total paralysis of the hand	1
Isolated paralysis of radial flexor of the wrist	1
Total	37

Distribution of Paralysis by Individual Muscles

(*Investigation of 36 Cases*)

	Total	Partial	Sum
Flexor carpi radialis	11	14	25
Flexor carpi ulnaris	7	13	20
Flexor pollicis longus	6	16	22
Flexor digitorum profundus	3	17	20
Extensor pollicis longus	10	14	24
Abductor pollicis longus	16	8	24
Extensor digitorum communis	13	16	29
Extensor pollicis brevis	18	9	27
Extensor carpi ulnaris	13	7	20
Extensor carpi radialis	14	8	22
Interossei	13	9	22
Thenar muscles	14		14
Sum total of muscles paralyzed	138	131	269

Distribution of Deformities

	Cases
Flail hand	8
Drop hand	17
Contracted hand or claw-hand	4
Total	36

As may be seen in this table of individual muscle distribution of the paralysis, there is a preponderance of the total paralysis over the partial paralysis in the extensor group and a preponderance of the partial paralysis over the total paralysis in the flexor group of the wrist and fingers.

The Paralytic Drop-hand.—The most frequent problem to be dealt with in spinal paralysis of the hand is that of paralytic drop-hand deformity due to paralysis of the extensors alone or to the preponderating paralysis of the extensors over that of the flexors. This preponderance of the extensor paralysis over the flexors, as encountered in old cases of infantile paralysis of the hand, is not merely the expression of the original distribution of the poliomyelitis, but also represents the subsequent damage to the muscles occurring in the chronic stage of paralysis which is brought about by the passive stretching of partially weakened extensor muscles. In this respect, the situation is entirely at par with that commonly observed in the extensor muscles of the foot. Here we know that the enormous preponderance of the extensor paralysis is partly due to a secondary loss of muscle power occurring during the chronic stage of the disease when the proper support or protection of the weakened extensor muscles has been neglected.

The most immediate requirement in the treatment of the drop-hand following poliomyelitis, as well as any other type of paralysis, is the preservation of the weakened extensor muscles by proper splinting. The hand must be splinted immediately and must be held in a hyperextended position. This is best done by a cockup splint (Robert Jones) reaching over the wrist to the first interphalangeal joint. It is not necessary to run a splint to the end of the fingers and beyond because the extensor muscles have little to do with the extension of the end and mid phalangeal joints. On the other hand, this position would be very conducive to producing a hyperextension in the metacarpophalangeal joints which, as will be seen later, is very hard to overcome and is very disabling in effect. It is very gratifying to see recent cases of infantile paralysis regain power in the extensor muscles, both of the wrist and of the fingers, under early and properly continued splinting in this position. Results are greatly enhanced by timely massage and active movements of the fingers. Massage may properly begin as soon as the tenderness has subsided and active motion should follow closely. The latter, however, should be very carefully supervised and should begin very insidiously, and great restrictions should be placed upon the

time of treatment as well as its frequency because of the danger of exhausting the extensor muscles. Under this treatment we have seen motion return in the extensors of the wrist and fingers a considerable time after the onset of the paralysis. It is safe to say that one year should be the minimum time for such conservative attempts to restore motion. However, one should not be guided by the amount of time elapsed alone but also by the clinical symptoms such as shrinkage, atrophy, and especially the electrical reactions.

When a residual drop-hand paralysis has been definitely established, the problem of dealing with the disabled hand becomes largely a surgical one. For the restoration of the lost function, two possibilities are open. The first is the transplantation of muscles to the back of the hand and wrist to substitute for the lost extensors. We believe that in infantile paralysis there are only exceptional cases which will lend themselves to the treatment by transplantation methods alone, because the muscle material available for transplantation is in most cases not sufficient to take care of extension of the wrist as well as that of the fingers. For this majority of cases, the other alternative must be considered, namely, the arthrodesis of the wrist joint; although no function is imparted to the wrist by arthrodesis, it is an excellent means of restoring the wrist to a high degree of stability in a desired position. In the writer's opinion, the stability of the wrist is so indispensable a requirement for the function of the fingers that no thought of any operative method should be entertained which does not fully guarantee a stable wrist, and this stability in proper position must be procured first. The arthrodesis which meets these requirements also makes available for transplantation use the flexor muscles of the wrist; these may then be carried upon the dorsum of the hand and used to procure active extension of the fingers.

The Technic or Arthrodesis of the Wrist.—An incision is made on the dorsum of the wrist between the tendons of the extensor indicis proprius and that of the long extensor of the thumb. After division of the fascia, the ligamentum carpi dorsale is divided. One now proceeds between the compartments of the long extensor of the thumb and that of the extensor of the index finger, drawing these muscles to the side. By stripping off the ligamentous apparatus as well as the capsule from the bones of the wrist, the lower end of the radius is exposed as well as the scaphoid and the os lunatum. From these bones a wedge is taken out with the osteotome. This wedge has a dorsal base and its slant is so calculated as to bring about complete adaptation of the raw bone surfaces in a position of hyperextension of 25° or 30°. This position is further secured by passing heavy sutures of chromic gut through drill holes in the bone or through the periosteum and by tying the sutures with the hand in hyperextension. The wound is now closed in layers and a plaster cast is applied reaching from the palm of the hand to midway between elbow and shoulder. Active motion of the fingers is begun in the cast within a week, or as soon

as the tenderness has disappeared. After a period of two months, the cast is removed and supplanted by a cockup splint. This latter is never removed except for treatment and it should remain for an additional three or four months, making the entire period of fixation about six months. There is not much danger from the adhesions of the extensor tendons if active motion is carried out early. We find that opening and closing the finger is not interfered with by arthrodesis (Plate XII, 1-4).

Regarding the proper time for the operation, it may be stated that it can be performed successfully at the age of eight years or even sooner. In younger children, the arthrodesis is naturally not complete, and passive extension beyond the position at operation is often possible to some slight degree. In none of the cases, however, was there a relapse into the flexion position after a point had been made of maintaining carefully the initial position of hyperextension in the cast and letting the latter remain for a sufficient length of time. Older children show, regularly, good bony fusion and a very stable wrist with no motion.

Reviewing the operative methods so far mentioned for the reconstruction of flail arm and hand, the situation may be briefly summed up in the following manner: The arthrodesis of the shoulder, providing for the arm a wide circle of motion and freeing it from its close adherence to the body line, is the keystone to the rehabilitation of the flail upper extremity and with it of the flail hand. It elevates the extremity to the horizontal plane wherein the member can be brought closer to the eye and the movements better controlled by vision. It also lifts the extremity out of the line of direct pull from its own weight.

The strain of weight of the forearm rests upon the hinged joint of the elbow. By imparting motion to the elbow by means of the muscle plasty already described, control is given of the back and forward movement of the forearm, though this is done only with a limited degree of power. The pronation and supination movement, if it cannot be obtained by direct muscle action, may yet be supplanted by substitutionary motion of the shoulder-blade. In this respect, the alternating action of the trapezius, the pectoralis major on one side, and the rhomboid muscles and the latissimus dorsi on the other side, are especially valuable. The development of this substitutionary rotatory motion is of high importance in the after treatment of the paralytic extremity.

The arthrodesis of the wrist finally provides that stability to the wrist and hand which is so essential for the play of the fingers. Upon the basis of this stabilizing operation, tendon transplantation may be carried out with much better promise of functional improvement than would be likely without the arthrodesis of the shoulder and wrist joint. Even in cases of total paralysis of the entire extremity, the possibility of giving some limited use to the arm by arthrodesis should be kept in mind. Several of these cases have been seen by the writer in which there was not a single muscle of the extremity preserved except some of

the scapulothoracic muscles. By carrying out arthrodesis in the three principal joints of the extremity, it is possible in some cases to create a condition in which at least as much function could be obtained as in instances of forearm amputations, when a suitable prothesis is being worn. In such a case, the motion of the extremity can be guided by the motion of the shoulder girdle, and the arm can be used similarly to a forearm stump or wrist stump and be made suitable for a number of simple operations. Some patients entertain the idea of amputation of their apparently entirely useless limb, but considering that one might procure a very stable arm with all joints in suitable position, a good deal may be gained by following this course.

Arthrodesis of Wrist in Infantile Paralysis

Name	Sex	Age	Dur. Par.	P. O. Observ.	Condition	Operation	Result	Additional Operations
J. B.	M	21 yrs.	8 yrs.	8 mos.	flail wrist	arth. of wrist	good	plasty elbow arth. of shoulder
H. S.	M	21 yrs.	8 yrs.	8 mos.	flail wrist	arth. of wrist	good	arth. of shoulder
V. N.	F	13 yrs.	10 yrs.	2 yrs.	par. drop wrist	arth. of wrist	good	plasty elbow and thumb
L. B.	M	16 yrs.	10 yrs.	1 year	flail wrist	arth. of wrist	good	plasty elbow arth. of shoulder
B. F.	F	12 yrs.	9 yrs.	10 mos.	flail hand	tendon trans. of wrist	poor	
P. K.	M	9 yrs.	7 yrs.	4 mos.	flail wrist	arth. of wrist	good	
T. G.	M	14 yrs.	7 yrs.	4 mos.	flail wrist	arth. of wrist	good	flexor plasty elbow
H. G.	M	8 yrs.	?		par. flail hand	arth. of wrist	und'd	arth. of shoulder

OPERATIONS

Types	Number of Cases	Results	Number of Cases
Arthrodesis alone	2	good	6
Arthrodesis of wrist combined with arthrodesis of shoulder	2	poor	1
Arthrodesis of shoulder plus elbow plasty	4	undetermined	1
Total	8	Total	8

(Plate XIII, 1–4).

Tendon Transplantation.—Tendon transplantation has a wide field in the reconstruction work of the paralytic hand, especially in the rehabilitation of the fingers. It has already been pointed out that motion may be imparted to the fingers directly from the muscles of the wrist

LEGEND FOR PLATE XII

TECHNIC OF ARTHRODESIS OF WRIST

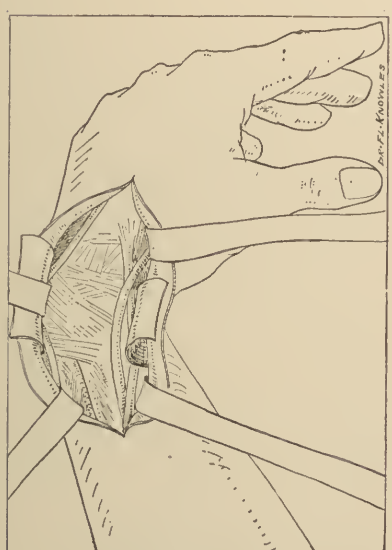
Fig. 1.—Incision and Exposure.

Fig. 2.—Dissection of Radius and Carpal Bones; Lines of Osteotomy.

Fig. 3.—Removal of Bone Wedge; Placing of Wires.

Fig. 4.—Tying of Wire Sutures; Closure.

PLATE XII



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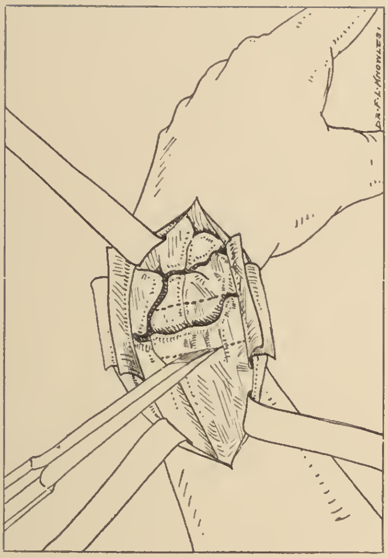

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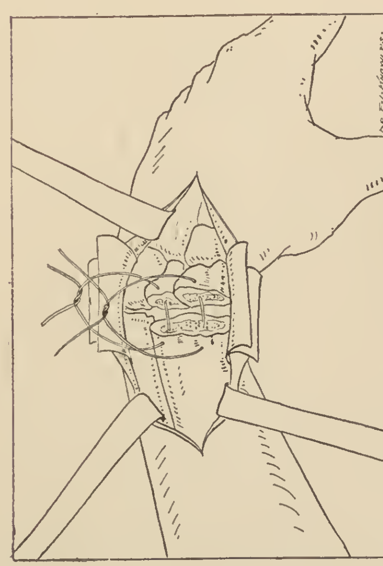

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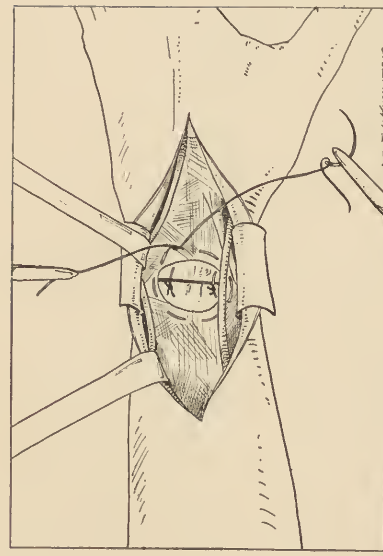

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LEGEND FOR PLATE XIII

Fig. 1.—L. D. Paralytic Flail Wrist; Result of Arthrodesis.

Fig. 2.—T. G. Paralytic Flail Wrist; Result of Arthrodesis.

Fig. 3.—E. S. Paralytic Flail Wrist.

Fig. 4.—E. S. Result of Arthrodesis.

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both from the flexors of the wrist and the extensors. Successful tendon transplantation generally presupposes a safe amount of available muscle material which is to be redistributed about the joint in such a manner as to procure not only motion but a satisfactory degree of muscle equilibrium as well. In the paralytic hand, the paralysis is rarely limited to the extensors alone and, even if so, the problem cannot readily be solved by tendon transplantation without arthrodesis. For instance, if we aim at independent extensor action of wrist and fingers, there would be required for transplantation at least four muscles to be taken from the flexor group; in infantile paralysis of the hand, these four muscles are rarely available. It is here where the arthrodesis of the wrist furnishes an excellent basis upon which further transplantation could be carried out with satisfactory results. All the flexors of the wrist become at once available for transplantation use.

Tendon Transplantation of the Flexor Carpi Ulnaris to the Extensors of the Fingers and of the Flexor Carpi Radialis to the Extensors of the Thumb.—An incision is made on the radial side of the flexor carpi ulnaris from the wrist halfway up the forearm. The flexor carpi ulnaris is dissected and isolated up to its insertion into the pisiform bone. The ulnar nerve and artery, lying under this tendon, are carefully dissected and retracted outward. The entire tendon of the muscle is then isolated and severed at its insertion into the pisiform bone. By retracting the flexor muscles of the fingers to the radial side, one then proceeds into the depth until the interosseous membrane is reached. The fibers of this membrane run obliquely from the ulna down to the radius. At a suitable distance above the upper border of the pronator quadratus, this membrane is perforated by a blunt instrument which is pushed forward on to the dorsal surface of the forearm in a direction corresponding to the line from the inner condyle of the humerus to the middle of the dorsal surface of the wrist. A dorsal incision is then made which exposes the extensor tendons of the fingers. The flexor carpi ulnaris is led through this incision and fastened side to side to the finger extensors. To this end, it is advisable to split the tendon into two halves, applying each half to the two inner and the two outer individual tendons of the common extensor of the fingers, respectively. The suture is carried out at a moderate tension of both the ulnaris tendon and the extensor tendons, and the extension position of the fingers is secured. The wound is then closed in layers. In six cases so operated, we have found no essential difficulty in the technic, the only point of importance being that, in isolating the ulnar artery with the nerve, it is necessary to retract it radialward so that it will lie between the flexor ulnaris and the common flexors of the fingers. When this detail is neglected, the ulnar artery will lie between the transplanted tendon and the ulna, and we occasionally found considerable circulatory disturbances immediately after operation caused by the impingement of the artery against the radial border of the ulna. This, however, never assumed a very serious degree and circulation was soon reëstablished. Active motion is begun as soon

as the condition of the wound permits, that is, from a few days to a week after the operation. From the viewpoint of innervation, there seems to be no difficulty in bringing about extensor action of the flexor carpi ulnaris. This is possibly due to the fact that this muscle normally contracts in forced extension of the fingers against resistance, because it is then used as a stabilizer of the wrist joint and therefore is, in a way, always in cerebral association with the motion of the extensors of the finger. In some cases, active extension of the fingers could be carried out distinctly within a week after operation. One should warn the patient, however, against overexertion.

When the flexor carpi radialis is used, it can be brought readily around the radial border of the radius to the dorsal surface of the thumb after it has been severed close to its insertion. This muscle will then maintain a practically straight course from its insertion to the dorsal surface of the radial metacarpal, and it can be brought out at the dorsum of the hand and fastened to the long extensor of the thumb by a short dorsal incision.

In the 6 cases in which transplantation of the flexor carpi ulnaris has been carried out, 5 concerned patients with poliomyelitic drop-hands. Of these the interosseous route for the flexor carpi ulnaris has been used in 3 cases, while in 2 cases the transplanted muscles were carried around the ulna and radius, respectively. The results were as follows: good or fair extension of the fingers was obtained in 3 cases; doubtful extension of the fingers in 1 case; and no extension of the fingers in 1 case.

There are some rare instances of extension contracture of the hand in poliomyelitic paralysis. These cases offer possibilities for tendon transplantation. The best result was obtained in a case in which transplantation of the extensors of the wrist to the flexors of the finger was carried out, supplemented by an arthrodesis of the wrist. The flexor motion of the fingers was rather weak at first but improved considerably under long-continued muscle educational treatment.

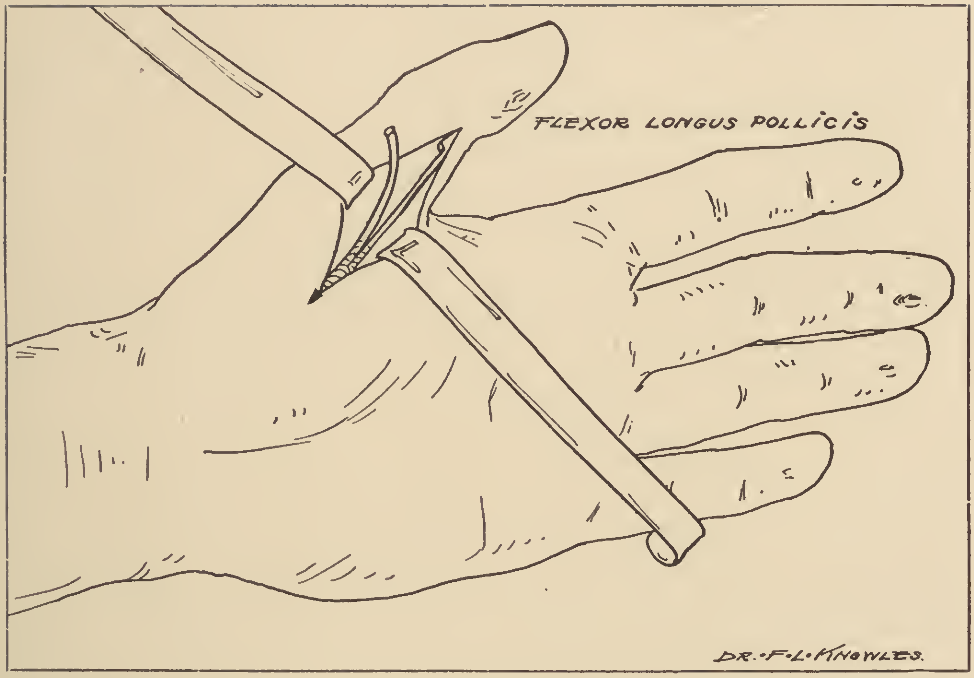
Thenar Paralysis.—The paralysis of the thenar muscles incapacitates the hand to a considerable degree. Even the more primitive motions of the hand depend upon opposition movement of the thumb, which is one of the principal functions of thenar muscles. To some extent, failure of opposition may be compensated by substitutionary motion, as has been stated previously. The lack of the abductor and short flexor muscles may be compensated partly by the action of the adductor of the thumb together with the long flexor. These muscles are not only capable of pressing the thumb toward the radial side of the index finger, making the hand capable of holding objects between these two fingers, but a sort of opposition of the thumb is also possible to a smaller degree. This will be accomplished better if the short flexor of the thumb is also working. In this event, flexion in the metacarpophalangeal joint can be carried out which, together with the adduction motion of the adductor of the thumb, will cause the thumb to cross the palm and

LEGEND FOR PLATE XIV

TECHNIC OF FLEXOR PLASTY OF THUMB

Fig. 1.—Splitting of the Tendon of the Flexor Longus Pollicis.

Fig. 2.—Periosteal Suture of Outer Half of Tendon to Base of Basal Phalanx.


FLEXOR LONGUS POLLICIS
DR. F. L. KNOWLES.

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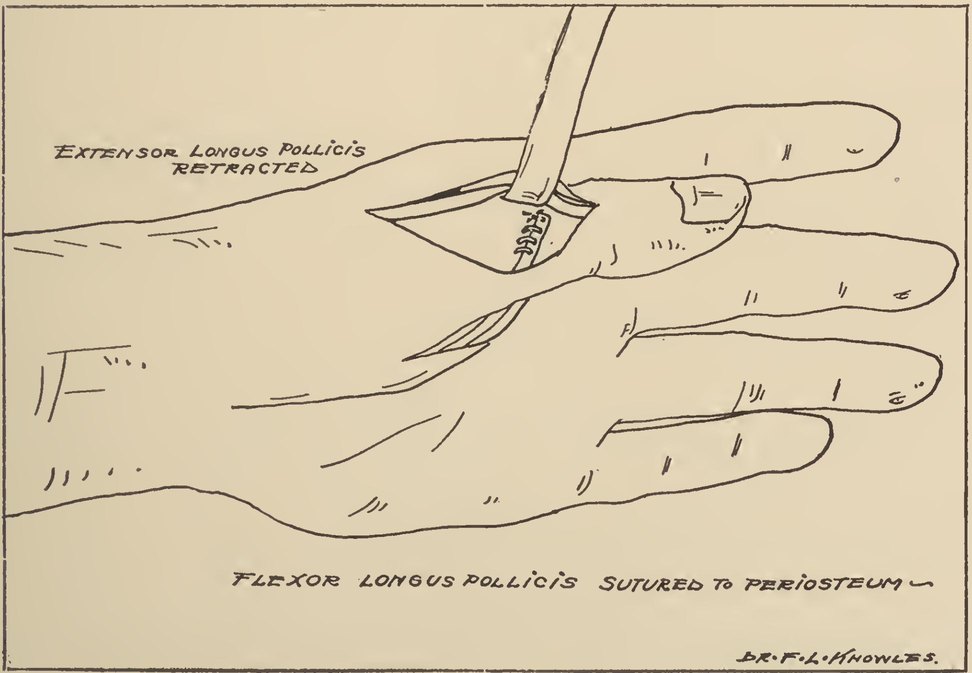
EXTENSOR LONGUS POLLICIS
RETRACTED
FLEXOR LONGUS POLLICIS SUTURED TO PERIOSTEUM
DR. F. L. KNOWLES.

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place itself near the base of the little finger. But, in most cases, the involvement of the muscles of the thenar is too extensive to make this substitutionary motion possible.

A simple method which will produce a motion of the thumb akin to that of the opponens pollicis, although as a rule not as forcible and not as complete, is the following:

An incision is made on the volar side of the thumb from the middle of the end phalanx downward to the middle of the thenar lying over, or better, slightly to the side of, the long flexor of the thumb. When making this incision, one should be careful not to carry it down too far so as not to interfere with the innervation by the thenar branches of the median nerve of such muscles of the thumb as might have escaped paralysis. The median nerve sends off its branches for the innervation of the opponens, abductor, and radial half of the short flexor of the thumb, at a point lying in the proximal half of the thenar eminence.

After the long flexor muscle of the thumb is exposed, its sheath is incised and the edges of it are held by fine forceps. Then the tendon is lifted out of its sheath and split longitudinally in two halves. The outer or radial half of the tendon is severed at its distal end, deflected upward, and the sheath of the long flexor is then reunited over the remaining ulnar half. Then the free radial half of the tendon is carried through a tunnel made in the soft parts, around the outer side of the metatarsal of the thumb to a point at the base of the basal phalanx well upon the dorsal surface. A short incision is made at this point. The tendon is drawn through, the periosteum of the basal phalanx exposed, and the tendon is sutured to the periosteum as dorsally as possible and close to the base of the basal phalanx. Then the wounds are closed. This simple procedure procures a secondary attachment to the long flexor of the thumb. When this muscle contracts, this attachment will cause the thumb to swing in a circle over the trapezium as a pivot, and this motion will bring the end of the thumb in opposition to the little finger to a degree sufficient for most of the ordinary motions of the thumb. This procedure was carried out in 9 cases, 5 of which were cases of infantile paralysis. Only in 1 case was the result doubtful. In the other 4, a satisfactory degree of opposition was obtained. By a careful muscle educational after treatment, the power of opposition can be developed to a considerable degree (Plate XIV, 1, 2).

Traumatic Paralysis.—Paralysis following injury of the peripheral nerves has come very much into the foreground due to the wide and extensive experiences which were amassed in the surgery of the recent war. The last few years have been productive of a great number of valuable contributions. In as much as they concern neurological or neurosurgical problems, it is not the intention of the writer to expatiate upon them in this treatise strictly devoted to orthopedic problems. However, there is no escape from the fact that many of the instances of peripheral paralysis from nerve lesions ultimately lead to distinctly orthopedic conditions and call for orthopedic measures of relief.

Excellent contributions in regard to the pathology and the treatment of peripheral nerve lesions as such have been made. The work of Tinel and others may serve as a source of reference for any of the pathological and clinical features presenting themselves in this type of neurological lesions. In the last analysis, the outcome of peripheral nerve lesions is based upon the question whether there is a complete or a partial interruption of the nerve. In cases of peripheral paralysis resulting in complete degeneration, both the faradic and galvanic current give evidence of what is known as reaction of degeneration. The typical feature of the latter is the inexcitability of the nerve to the faradic and galvanic currents, the inexcitability of the muscle to the faradic current, and the hyperexcitability of the muscle to the galvanic current at its motor point, with polar inversion and slow contraction. It seems that this slow contraction is of the greatest importance, as it is sufficient to characterize reaction of degeneration even without a distinct degree of hyperexcitability and without polar inversion.

On the other hand, the returning regeneration of the nerve following complete or partial interruption ushers in symptoms in exactly the opposite order. Galvanic hyperexcitability diminishes, polar inversion becomes polar equality, finally returning to normal form. There is an acceleration of the slow contraction. Then follows a reappearance of the faradic sensibility and faradic contraction and finally the normal excitability of the nerve returns. It is the merit of later investigators, especially Tinel, to have pointed out the difference between the syndromes of complete and those of partial interruption. In the latter instances, there is a reaction of partial degeneration. There may be a hypo-excitability of the nerves and muscles to the faradic current. There may be a hyperexcitability of the muscles to the galvanic current and total inexcitability of the nerves. There may be only one factor lacking for complete reaction of degeneration, for instance, the contraction of the muscle not being very slow or slow to the positive and quick to the negative pole. Polar inversion also may fail. All authors agree that the differentiation between partial and total degeneration of the nerve is of greatest importance in determining the state of the injured nerve and indirectly the indications for treatment. It is generally recognized that evidence of complete severance of the nerve is an indication for operative repair.

From the syndrome of partially or totally injured nerves, the symptoms of nerve exhaustion should be separated. These may be found in a weakened muscle or in a muscle in a state of exhaustion or oftener during the process of muscle regeneration and consist in unequal responses to successive faradic irritation, the muscle missing from time to time in its contractions.

Finally, signs of hyperexcitability of the muscles should also be noted, since they are present occasionally in cases of neuritis or nerve irritation. This condition is characterized mainly by tonic contractions persisting after galvanic exitation has ceased.

Subject to reaction of degeneration are all muscles paralyzed by injury to the peripheral or lower motor neurone, that is, lesions of the peripheral nerves, lesions of the anterior roots, or, finally, lesions of the anterior horn cells themselves, as is the case in infantile paralysis.

It is now being generally recognized that the surgical procedure of choice to be applied to severed peripheral nerves is that of end-to-end suture. All other operative methods, such as splicing, cable towing, nerve interposition, etc., are of extremely doubtful value. The only reliable method in which acceptable percentages of return of power have been observed is that of end-to-end suture. The statistics of D. Lewis, Blencke, and many others show the superiority of this operative method over the others.

In formulating statistical conclusion, the element of time is of greatest importance. The time allotted for regeneration of peripheral nerves has generally been too short. Especially in long nerves which are injured at a considerable distance from the neuromotor end, a very considerable time is required for regeneration, not infrequently one and a half to two years or more. For this reason, the statistics of the late war promise to improve as the time goes on.

From the orthopedic point of view, two problems are of special interest: the first is the preservation of the muscle during the period required for regeneration of the nerve. The relaxation of the apparently paralyzed muscle is of greatest importance, just as it is in the early treatment of infantile paralysis. Muscles involved in the peripheral nerve paralysis must be kept rigidly in a position which will facilitate their regeneration by the time the neuromotor conduct is reëstablished. Only by proper splinting, which prevents pull and strain on the muscle, can such an end be accomplished.

In discussing the surgery of peripheral nerves, Sir Barkeley Moynihan sums up his experiences gathered during the Great War in the following statement:

> An early examination should be made of all wounds in which division of the nerve trunk is probable. In cases of secondary suture following Carrel-Dakin treatment, nerve suture should be included in the operative plan.

He emphasizes that nerve grafting or any other of the more or less fantastic methods which have been devised from time to time are of no value whatsoever. This includes the splicing of the nerves as well as the formation of nerve flaps.

The situation becomes purely orthopedic in many instances in which nerve suture is either impossible or, if carried out, is not followed by regeneration of nerve or muscles; in this event, the choice must be made between the methods of tendon transplantation and those of joint fixation, or a combination of both.

Musculospiral Paralysis.—According to common experience, musculospiral paralysis is the most common of the peripheral nerve lesions

in civil as well as in military surgery. It constitutes about 25 per cent of peripheral nerve lesions. Its frequency is explained largely by the frequency of injury to the humerus and the close proximity of the nerve to the bone which makes a lesion of the nerve a very frequent occurrence. Out of 22 cases of traumatic peripheral paralysis seen by the writer in four years, 6 were cases of musculospiral paralysis following fracture of the humerus. One additional case of musculospiral paralysis followed a contusion of the humerus without fracture.

The fracture being situated more often in the upper third of the humerus, it is often followed by complete musculospiral paralysis of the hand and forearm. The supinator longus, the supinator brevis, and the extensors of the wrist, the extensors of the thumb, the extensor ossis metacarpi pollicis, and the extensors of the fingers are paralyzed. In establishing the seat of nerve injury as well as the extent of the paralysis, it is necessary to make a dissociative diagnosis in cases in which the exact location of the paralysis does not become evident from direct traces left by the trauma.

Musculospiral paralysis above the supinator longus involves this latter muscle and besides the radial extensors, the extensor carpi ulnaris, the extensors of the fingers, leaving the triceps muscle untouched as this muscle receives its innervation higher up. Total paralysis, on the other hand, involves the triceps muscle and abolishes the olecranon reflex.

Where the seat of injury is below the level of the supinator longus, the preservation of this muscle is demonstrated by its active contraction which raises it into strong relief on the radial side of the elbow. Very close to the supply of the supinator longus is that of the extensor carpi radialis, so that in paralysis of the nerve below the supinator longus, at least, the long radial extensor may escape injury. Below the radial extensors, the seat of injury may be located by the fact that, while the hand can be put into dorsal flexion, the fingers cannot, since all the dorsal wrist-extensors escape injury except the extensor carpi ulnaris which receives its nerve branches at a much lower level.

Nerve lesion below the branches for the extensor digitorum communis will preserve the ability of extension of the wrist as well as of the fingers, but the extensor ossis metacarpi pollicis and the long extensor of the thumb as well as the extensor of the index finger are paralyzed, indicating that the seat of injury is at a level between the supply of the common extensors and the supply of the latter named muscles.

A difficulty arises quite often from the peculiar faculty of the patient to supply by substitutionary motion what has been lost by paralysis of the musculospiral nerve. Extension of the wrist is often accomplished by a forced flexion of the fingers. Therefore, the simultaneous extension of the wrist and extension of the finger is a valuable test for the integrity of the musculospiral nerve as far as its supply to the forearm muscles is concerned.

On the other hand, extension of the fingers is often accomplished by forcible flexion of the wrist. In the latter instance, the extension of the finger is entirely mechanical, due to the passive stretching of the extensor tendons when the wrist goes into flexion.

In splinting the hand following a musculospiral paralysis, the principal point is that the hand be placed in hyperextension in the wrist and that the splint should reach up to the proximal phalangeal joints of the fingers and not any farther, because, as has been mentioned already, the extensors of the fingers have no part in extending the middle and end phalanges, this being strictly a function of the interossei and lumbricales. It is, therefore, not necessary to extend the splint up to or beyond the tips of the fingers and it is often detrimental as it predisposes to other deformities.

Case Reports.—B. N., 7 years. Traumatic musculospiral paralysis. The patient broke his left arm by fall 2 months ago. Has had very little use of the hand since injury. The examination showed a paralysis of the extensors of the finger of the left hand and a partial paralysis of the extensors of the wrist. The patient was at once placed in a splint, which held his wrist and palm in hyperextension. After 4 months, there was complete disappearance of paralysis and normal extension of fingers and wrist.

C. B., 38 years. The patient had an operation on the left breast a year ago followed by a secondary operation for local recurrence 10 months ago, and a third operation 8 months ago; the latter was performed for the removal of glands in the axilla. Following the third operation, the patient developed a paralysis of the left arm with loss of control of the finger motion. The examination showed a partial paralysis of the musculospiral and median nerves.

The hand was put in a cockup splint and the patient instructed in massage. When seen 2 months later, there was good action of both extensors of the wrist and those of the fingers. There was still slight atrophy of the thenar muscle but practically all the motion of the thenar had returned. These cases demonstrated the possibilities of conservative treatment in cases of partial paralysis of the musculospiral nerve.

The question of operative treatment of the permanent musculospiral paralysis not remediable by nerve suture, or not remedied by it, is so entirely an orthopedic problem that we believe its closer consideration to be justified. Among the operative measures, arthrodesis of the wrist is again in the foreground. It is the most valuable and most reliable procedure to procure both stability and position, two advantages which will go a long way to offset the disadvantage of lost wrist motion. The technic of arthrodesis has already been described in the chapter on the poliomyelitic flail hand.

The indication for arthrodesis, we believe, arises in cases of total musculospiral paralysis of the wrist and fingers where it would be doubtful that both wrist extension and finger extension could be procured by tendon transplantation.

As regards this latter procedure, several methods have been advocated, the foremost of which is that of Robert Jones:

The pronator radii teres is transplanted to the extensor carpi radialis, longior and brevior.

Then, the flexor carpi ulnaris is transplanted to the extensor tendons of the three ulnar fingers.

Lastly, the flexor carpi radialis is transplanted to the extensor of the thumb and index finger.

A modification of this method is that of Harold Stiles. He transplants the palmaris longus to the extensor ossis metacarpi pollicis and extensor pollicis brevis; the flexor carpi radialis is transplanted to the extensors of fingers and thumb; finally, the pronator radii teres is transplanted to the extensor carpi radialis, longior and brevior. In this method, all these muscles are swung around the radial border of the radius and can be reached from one volar incision.

Stoffel transplants the flexor carpi radialis to the extensor carpi radialis, longior and brevior, the flexor digitorum sublimis to the abductor pollicis longus and extensor pollicis brevis, and the flexor carpi ulnaris to the extensor digitorum communis and extensor pollicis longus.

There are many, however, who include a stabilizing operation on the wrist in the operative plan of tendon transplantation. Baisch, for instance, performs a tenodesis of the wrist and a transplantation of the flexor carpi radialis and ulnaris to the extensor pollicis longus and extensor digitorum communis.

In several cases, the writer has combined both the methods of arthrodesis and tendon transplantation.

H. W., 25 years. Total musculospiral paralysis due to compound fracture of the left humerus occasioned by the arm being caught in a rotating belt. There was a paralytic drop-hand involving all extensors of the wrist as well as of the fingers and of the thumb. An area of anesthesia was present on the radial side of the dorsum of the forearm wrist and hand. The operation consisted in:

1. Arthrodesis of the wrist.

2. Tendon transplantation of the flexor carpi radialis around the radius to the extensor pollicis longus.

3. The transplantation of the flexor carpi ulnaris to the extensor digitorum communis through the interosseous route.

This latter method has been described on a former occasion. The result was satisfactory, active extension of the thumb and fingers being possible (Plate XVII, 1, 2).

Traumatic Paralysis of the Brachial Plexus.—Severe injuries to the shoulder joint, lacerating wounds, or gunshot injuries to the inner side of the humerus or the axilla, may be complicated by severe lesions of the nerve trunks constituting the brachial plexus. Several cases of this kind have come to the writer's observation. In the case of a young boy 13 years old, the brachial plexus was injured by the cut of a barbed-wire fence, causing complete interruption of all the main trunks of the

LEGEND FOR PLATE XV

Fig. 1.—F. N. Scar Contractures of Wrist. Live-wire Burn. After Plasties of Flexor Tendons.

Fig. 2.—H. S. Scar Contracture of Hand. Live-wire Burn. After Plasty of Flexor Tendons.

Fig. 3.—H. S. Trick Motion; Extension of Fingers by Flexion of Wrist.

Fig. 4.—H. S. Flexion of Fingers by Extension of Wrist.

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LEGEND FOR PLATE XVI

FIG. 1.—P. H. TRAUMATIC PARALYSIS OF THUMB. AFTER FLEXOR PLASTY OF THUMB. RESULT OF OPERATION.

FIG. 2.—P. H. RESULT OF OPERATION.

FIG. 3.—P. H. RESULT OF OPERATION.

FIG. 4.—E. G. SCAR CONTRACTURE OF THUMB.

FIG. 5.—E. G. RESULT AFTER FLEXOR PLASTY.

PLATE XVI

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LEGEND FOR PLATE XVII

FIG. 1.—H. W. MUSCULOSPIRAL PALSY. DROP WRIST.

FIG. 2.—H. W. AFTER ARTHRODESIS OF WRIST AND INTEROSSEOUS TRANSPLANTATION OF FLEXORS.

FIG. 3.—D. C. TRAUMATIC PARALYSIS OF BRACHIAL PLEXUS.

FIG. 4.—J. O. MUSCULOSPIRAL PALSY. DROP WRIST.

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brachial plexus together with severance of the brachial artery (Plate XVII, 3-4).

Regarding this latter point, we know that a severance of the brachial artery, if not too high in the axilla, does not necessarily mean ischemia of the limb with subsequent gangrene. Two cases were observed in which this artery was cut and the collateral circulation proved sufficient to preserve the life of the limb.

Primary nerve suture was carried out in the case mentioned, both on the musculospiral and median nerves, though no return of function has been observed at the time of this writing. In cases of failure to restore function by nerve suture when the three main trunks of the brachial plexus are severed, there remains a total paralysis of the limb and the situation will parallel that of total paralysis of the arm following poliomyelitis. These extreme cases warrant the attempt to perform an arthrodesis in the three principal joints of the extremity in position advantageous to function, namely, abduction of the shoulder, flexion of 70° to 90° in the elbow, and extension of the wrist.

Traumatic Paralysis of the Thenar.—In a number of cases, traumatic paralysis of the thenar was observed, occasioned by injury to the median nerve at its point of entry into the thenar with destruction of the nerve branches which supply the thenar muscles. The result of such injury is a severe disability of the thumb. It is held adducted in the same plane with the palm, having entirely lost its power of opposition, and there is no possibility of a gripping action of the figners. The thenar muscles are found atrophic. While the use of the hand is thus greatly limited, objects can still be held between thumb and index fingers by action of the adductor of the thumb supplied by the ulnar nerve. This condition can be improved operatively by the same method which has been employed in thenar palsy following anterior poliomyelitis. One will find after this operation that the function of the hand becomes noticeably increased, and especially if a thorough course of muscle educational exercises follows the operation, the gripping power of the hand will become continuously better.

H. S., 16 years. Live-wire burn received 5 years ago, injuring both median and ulnar nerves. A dense scar reaching almost to the bone at the lower end of the forearm not only destroyed the ulnar nerve but also the median and with it the total supply to the thenar. The result of this combined nerve lesion was first an ulnar claw-hand deformity with hyperextension at the metacarpophalangeal joints and flexion of the fingers due to the loss of interossei and lumbricales. Aside from this, there was also a marked degree of atrophy in the palm and dorsum of the hand in the spaces between the metacarpals. The thumb was adducted in a plane slightly behind that of the palm of the hand, and the power of opposition of the thumb absolutely lost. In this case, the injury of the long flexor tensors was first repaired by tendon plasties in the forearm. The disability of the thumb was then taken care of by flexor plasty, making use of the functionating long flexor tendon

of the thumb in a manner already described. The result was ability of opposing the thumb, which was one of the principal factors of the subsequent functional improvement of the hand, to which was added the gradual increase of flexor motion in the fingers (Plate XV, 1-4).

The situation of the adducted thumb due to thenar palsy will be encountered on further occasions just as it has been found in poliomyelitic thenar palsy and in traumatic paralysis of the thenar. The method described has given thorough satisfaction in all situations in which the tendon plasty of the long flexor tendon of the thumb was indicated. Only in cases of error in technic, or of functional impairment of the long flexor tendon of the thumb itself (errors of indication), did the operation fail of its purpose of procuring opposition power to the thumb (Plate XVI. 1-5).

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CHAPTER V

CONTRACTURES OF WRIST AND FINGERS

CHRONIC INFLAMMATORY CONTRACTURES

The contractures of the hand and fingers which follow inflammatory conditions of the structures of the fingers, hand and forearm, owe their pathological development to an extension of the inflammatory process along certain anatomical channels, foremost of which are the systems of the tendon sheaths and the fascial spaces.

When the tendon sheaths surrounding the thumb and fingers become involved in infection, their endothelial lining disappears and synovial cavities become obliterated. Finally, a complete fibrous union is established between the tendons and their sheaths. In the case of the finger flexors, which are the tendons most commonly involved, this means a position of flexion in mid and end phalangeal joints, rigidly maintained by peritendinous adhesions. At the wrist, the inflammation involves the radial and ulnar bursa and extends from here into the intermuscular spaces of the forearm. The ulnar and radial bursae finally become completely obliterated and the tendons are clustered together in a common bundle. In the palm, the tendons of index, middle, and ring finger may be isolated as they have their individual tendon sheath, but the sheath of the little finger and of the thumb commonly communicates with the ulnar and radial bursa, respectively, so that inflammations of these bursae will usually result in severest contractures of the two marginal digits.

On the dorsum of the hand, the tendons become a part of the connective tissue mass and their isolation becomes extremely difficult. It is quite common in the course of infection that inflammation extends into the interphalangeal joints and not infrequently it involves the wrist joint also. In this event, the phalangeal joints will be found firmly fixed in flexion; the metacarpophalangeal joint, usually not involved, remains in hyperextension. The numerous periarticular adhesions, as well as the changes occurring in the joints themselves, make the attempts at correction very difficult. In severe cases, the involvement of the wrist joint leads to ankylosis of the wrist in distorted positions. The muscles of the forearm themselves take part in inflammatory changes. They may be found indurated by a marked proliferation of connective tissue and in extreme cases the muscles are transformed into a dense mass of scar tissue. In the palm itself, the changes in the interossei and lumbrical muscles are most prominent. Frequently they are entirely

destroyed either by direct action of the inflammation or by grave circulatory changes incident to it.

The study of the finger contractures of inflammatory nature is by no means a simple problem. A contracted or deformed hand develops from a combination of factors, biological and mechanical; and not only the pathological process but the dynamic forces also must be considered in the development of contractures.

Starting with the position of the wrist, it must be kept in mind that the latter largely influences the subsequent position of the fingers. If the infection of the bursa or the forearm spaces spreads into the wrist joint and causes a suppurative arthritis, the immediate pathological result will be a contracture in flexion position, which, in time, may become flexion ankylosis. In some cases the infection remains confined to the wrist joint alone; it may destroy the articular surfaces and cause the wrist to become ankylosed in flexion. But more often the infection follows the synovial sheaths and also involves the joints of the fingers; then the resulting deformity will be one of flexion of the fingers in the mid and end phalangeal joints also. The metacarpophalangeal joints are singularly exempt from involvement in the inflammatory process, presumably because they have very strong ligamentous reinforcements which separate these joints from the inflamed sheaths of the flexor tendons.

So much for the purely pathological origin of the contracture. But there are also at work dynamic forces which must be considered. The flexion position of the wrist and fingers, whether purely contractural or inflammatory, carries with it such a relaxation of the flexor muscles that the equilibrium invariably shifts towards the side of the extensors of the fingers with the result that the metacarpophalangeal joints become hyperextended. The result is the characteristic claw-hand attitude, seen in some of the inflammatory contractures. In many other cases, flexion contracture exists in wrist and fingers without hyperextension in metacarpophalangeal joints; in these instances, however, the contractures are, as a rule, not extreme, especially the flexion in the wrist.

The clinical picture of postinflammatory contractures is so characteristic that it can hardly be mistaken. The glossy, atrophic skin, the atrophy of the thenar and hypothenar muscles, and the atrophy of the interossei are the most prominent symptoms. The induration of the forearm and shrinkage of the forearm muscles furnish further evidence, to which are finally added the characteristic contractures already described. Finally, numerous operative scars usually testify to the more or less adequate attempts made during the acute stage to localize the infection. The thumb takes part in the deformity by flexion contracture of the end phalangeal joint, and, to a lesser degree, of the basal phalanx also.

Returning to the contractures of the individual fingers, it has already been said that, especially in the fifth, the flexion contracture may become

extreme in mid and end phalangeal joints. To a lesser degree, we find flexion contractures in the third, fourth, and index finger, yet all these fingers may show motion in metacarpophalangeal joints. The severity of the case depends very largely upon the degree to which there is an upward spread of the infection with involvement of the wrist and the forearm spaces and muscles. Such a complication means the destruction and cicatrization of tendons over a long distance, and also the contracture and shrinkage of the forearm muscles so essential in producing the most intractable claw-hand deformities.

In a number of cases, in which the tendon sheath infection has become more localized, contractures develop to a much lesser degree; the synovitic adhesions are much less rigid, the play of the fingers is less impaired. The contractures of the fingers are not nearly so extreme as in cases where the infection had spread upward to the wrist and into the forearm spaces.

Adequate knowledge of the anatomy of the synovial extensions and fascial spaces in forearm and hand is indispensable for the early surgical treatment of these deformities. Although not within the scope of this writing, the prophylaxis of inflammatory contractures of hand and fingers must at least be mentioned. It is the prophylactic measures upon which are centered the best hopes for the salvage of the hand. This means not only very early interference, but one that is guided by precise knowledge of anatomy of structures affected and the routes of inflammatory extension (Kanavel, Beye).

Prevention of deformity is the keynote to the treatment of hand and forearm infections. But the frequency of postinflammatory contractures furnishes a peculiar comment on this principle. Many of these infections are so difficult to handle in their acute stages that deformity is nearly unavoidable. Nevertheless if more stress were laid upon the details of position and splinting, a good deal of deformity could be prevented.

From the viewpoint of the orthopedic surgeon, the problem involves the correction of already established contractures and deformities. They may yield to conservative or operative methods, or may resist either. In the choice of the method and the time for its application, in the planning of postoperative measures to secure and advance operative results, a good deal of careful judgment is necessary. It is especially desirable that the after treatment be carefully planned and every detail be covered by thorough consideration.

Conservative Methods.—In selecting the time for the correction of deformities following infections, one is, first of all, greatly restrained by the fact that the tissues involved very likely harbor latent foci of infection. In the soft tissues, and especially in the bones and joints, foci of residual inflammation are present, ready to break out into violence upon slight provocation. Foremost among such cases are compound fractures of gunshot wounds of the fingers, wrist, or forearm. These call for a great amount of precaution. Inflammation of the tendon and tendon sheaths following wounds of hand and fingers, and

especially those which follow crushing injuries often complicated by involvement of the joints, require above all the greatest amount of care. As a rule one may say that the time limit set before any forcible manipulation or operation is undertaken should be not less than one year after subsidence of all inflammatory symptoms, in the case of osteomyelitis and joint involvement, and six months if the inflammation involves the soft parts only. So great is the danger of recurrence of the inflammatory condition that even for the performance of merely corrective manipulations a liberal time limit after subsidence of active symptoms must be allowed. For instance, in correcting the faulty position of the wrist following extensive tendosynovitis and infection of the fascial spaces, the manipulation of the wrist joint is often followed by violent flare-ups with disastrous consequences. In case of doubt it is good practice to apply a gentle massage to the fingers and wrist and very careful passive motion. If well tolerated this can be increased gradually, and finally go the extent of passive correction with or without anesthesia.

If the condition of the hand is ready for the application of manipulative correction, the question arises, how much can be accomplished by it? Contractures of the phalangeal joints due to peritendinous adhesions, if not extreme, as well as periarticular adhesions, yield to moderate passive stretching under ether. No great amount of force should ever be applied. But in several instances, the writer observed the giving of adhesions about the finger joints by gentle stretching under anesthesia and the result of correction could be maintained subsequently by proper splinting and physiotherapy.

It is much more difficult to correct hyperextension in the metacarpophalangeal joints. It is here that often one has to resort to operative methods. In the wrist the flexion contracture is usually so great and the shortening of the powerful flexors so considerable that operative means are needed even if there is no direct involvement of the wrist joint. Where the wrist joint is involved and true ankylosis is established, nothing short of resection will restore proper position. Fibrous and periarticular adhesion often yield to manual correction.

In maintaining the correction obtained by passive manipulation, the postoperative management is a most important factor. One must never forget that breaking up adhesions is often followed by hemorrhage into the synovial sacs which will promptly furnish new adhesions by organization of the blood-clots, and nothing would be gained unless external splinting is so applied that it will, from the very beginning of correction, counteract the tendency to contracture. For the fingers, the writer used to great advantage individual finger splints, which consist of a distal ring with a dorsal tongue and are made of malleable steel so that they can be adapted readily to the position of the finger joints (Grund). These splints are used with or without forcible correction. When the finger correction is attempted gradually, these splints are bent into proper shape and care is taken that the pressure upon the knuckles of

the fingers is not too great and does not cause complications. It is better to treat fingers individually than to have a common splint for all.

For the correction of contracture in the metacarpophalangeal joints, a splint is used which combines both the cockup and traction arrangement. The latter consists of a strong glove pulled over the fingers and a system of traction straps attached to the glove. The straps, sewed to the glove, pull the basal phalanges of the finger into flexion and are attached to a rod which is fastened at an angle to the upper end of the cockup splint. One will find that a fair number of cases of synovitic finger contractures is amenable to correction by bloodless methods. The milder cases yield to passive stretching without anesthesia, combined with proper splinting and good after care. The latter is always an indispensable part of the treatment, without which no permanent results are possible.

The after treatment following forcible correction of finger joints should begin as soon as the tenderness disappears and the swelling subsides. In some cases it is advantageous to apply a plaster cast for a few days following forcible correction, because of the better immobilization. After a few days the cast may be replaced by splints and massage and active motion may be started. Active motion of the fingers should be encouraged from the very moment the tenderness subsides. One should wait with passive motion until the postoperative signs of irritation have disappeared (Plates XIX, XX).

Operative Methods.—In many cases the contraction of fingers or wrist joints is resistant either to mechanical treatment or forcible manipulation. This is especially true in contraction involving the thumb and little finger, as well as in contractures involving the wrist. All instances of true ankylosis and many of fibrous ankylosis in the joints will require surgical interference.

For the relief of contractures due to shortened finger tendons, the operative lengthening of tendons, rather than the subcutaneous tenotomies, should be considered.

Tenoplasty.—Tenoplastic technic in contractures of the wrist and fingers should be guided first of all by the general principles governing tendon surgery. A faultless asepsis is, above all, a condition without which no operation can hope to gain any results. Regarding the special technic, the following rules should be observed:

Avoid if possible median incision, because this invites the formation of adhesions between skin and tendon.

Handle the tendons with greatest care and gentleness; they are often friable and fray out easily in chronic inflammatory conditions.

Suture accurately and thoroughly.

One should attempt to reconstruct the tendon sheath; surrounding fascial tissue is to be used, if available; if not, the sheaths should be reconstructed with the aid of free fascial grafts.

The adhesions covering the tendons must be carefully resected, and

for this purpose the use of a cataract knife or a very fine scalpel is necessary.

The lengthening itself is best carried out by a Z-shaped incision which splits the tendon, allowing the two halves to glide over each other. Very fine catgut is a good suture material. The sutures must be laid with great care in a way which will avoid cutting through. Bunnell's method of suturing tendons is the most accurate procedure. He uses specially made metal clamps which hold the tendon while the suture is applied. The needle is carried through slots in the clamp in such a fashion that a cross stitch results which tightly grips the tendon without cutting it. Of the greatest importance is the proper attention given to the tendon after it has been lengthened. There must be a certain medium tension which should be great enough to give the muscle potential power and yet it must not be so great as to interfere with the tendon suture on the one hand and with the vitality of the muscle tissue on the other, because we know that overtension is of paralyzing influence upon the muscle tissue and favors muscle atrophy and degeneration (Mayer).

In forearm plasties, enough fascial tissue is at hand, in most cases, to cover the surface of the tendon against the superficial fascia and skin. Where this is not the case it is advisable to transplant fascia from the thigh. The necessity of reconstructing, as far as possible, the individual tendon sheath has already been mentioned.

It is better to apply a plaster cast in proper position following operation than to rely upon a splint which never gives the same amount of fixation. Within a few days the cast may be replaced by the splint and the after treatment begun. With the wound healing progressing satisfactorily, a few days or a week is a sufficient time of rest.

Special Problems—*Osteotomy.*—The osteotomy of the metacarpals to overcome hyperextension position in the metacarpophalangeal joint was carried out in one instance: Patient, 25 years of age, had experienced several lacerations of forearm, wrist and fingers by an industrial accident. The injury resulted in extensive scar formation which brought about a contracted claw-hand with flexor contraction of wrist and fingers and hyperextension in the metacarpophalangeal joints. The flexion contractures were corrected by tendoplasties without special difficulties. The hyperextension in the metacarpophalangeal joints resisted all operative attempts, such as lengthening of the tendons, resection of scar tissue, etc. Correction was finally obtained by osteotomies of the metacarpals about three-fourths of an inch proximally to the head and by subsequently kinking the metacarpal head toward the volar surface (Plate XIX, 2, 3).

Osteotomy and Wedge Resection.—In several cases osteotomy and wedge resection were carried out to stabilize the wrist in the desired position. The technic varies in no way from the one already described for arthrodesis of the wrist in paralytic cases.

Tendon Bridging.—Necessity of bridging gaps in tendons arises in tendon defects not remediable by simple tenoplasty.

In one instance the tendon of the palmaris longus was used to fill a gap in the flexor of the fourth finger. The operation requires long incisions and careful exposure of the tendons. It also requires painstaking suture of the gap and the avoidance of bulky knots. Fascia flaps or fat flaps are used to cover the tendon grafts.

In 19 cases operated, the following methods were used:

Table of Operations

	Cases
Flexor plasty of the thumb	1
Tenoplasties	7
Tenolysis and sheath reconstructions	3
Manipulative correction	4
Subcutaneous tenotomies	1
Tendon grafts	1
Osteotomy of wrist	1
Osteotomy of metacarpal heads	1
	19 operations

(Plates XVI, XIX, XX).

DERMOGENETIC SCAR CONTRACTURES

Cicatricial contractures following burns in the region of wrist and fingers offer a fertile field of technical problems. The treatment of these contractures is conservative only to a lesser degree, and mostly in the formative stages of the contractures when the scar is young and will yield to mechanical devices. Suitable splints have been described in previous chapters for the correction of inflammatory contractures of the hand. Their application in contractures of this type offers no new angles for discussion, except that, in the stage of scar formation and in extensive and painful lesions, great difficulties must be overcome which severely tax the ingenuity and patience of the surgeon.

In the chronic stage, many of the cases require operative methods, as the stretching of an already formed scar following burns is possible only to a very limited extent.

Scar formations on the dorsum of the hand, even if not involving the tendons themselves, are a serious obstacle to flexion of the hand. If on the volar surface, an equally resistant flexion deformity will result. Extensive burns of the fingers leave the latter usually in a contracted position in all joints, and, in some severe cases in which the palm has been involved as well as the dorsum of the hand, the fingers are placed

LEGEND FOR PLATE XVIII

Fig. 1.—T. McG. Scar Contracture of Elbow (Burn).

Fig. 2.—T. McG. After Italian Flap Plasty.

Fig. 3.—S. B. Scar-bound Extensor Tendon of Fourth Finger before Operation.

Fig. 4.—C. H. Scar-bound Flexor Tendon. After Tendon Plasty. Good Closure of Fist.

Fig. 5.—Pieri Method for Relief of Scar Contracture of Thumb.

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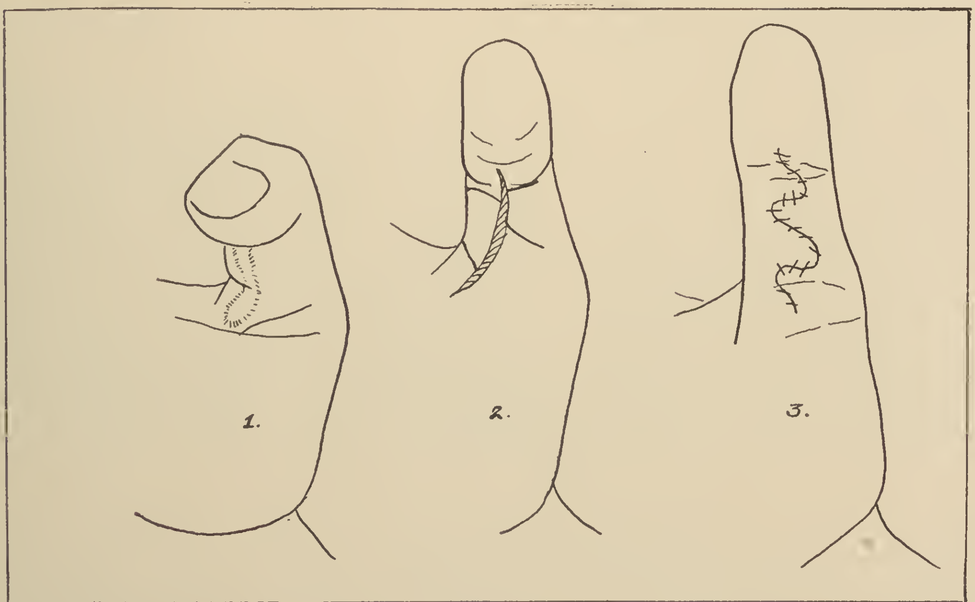

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LEGEND FOR PLATE XIX

Fig. 1.—E. G. Tenosynovitic Contracture of Thumb. After Operation.

Fig. 2.—F. A. Tenosynovitic Claw-hand before Tenoplasties.

Fig. 3.—F. A. After Tenoplasties.

Fig. 4.—Supination Splint (Dr. Funsten).

Fig. 5.—Ring Finger Splint.

Fig. 6.—Author's Glove Traction Splint.

Fig. 7.—G. T. Tenosynovitic Contracture of Hand. Scar-bound Cutaneous (Ulnar) Nerve.

PLATE XIX

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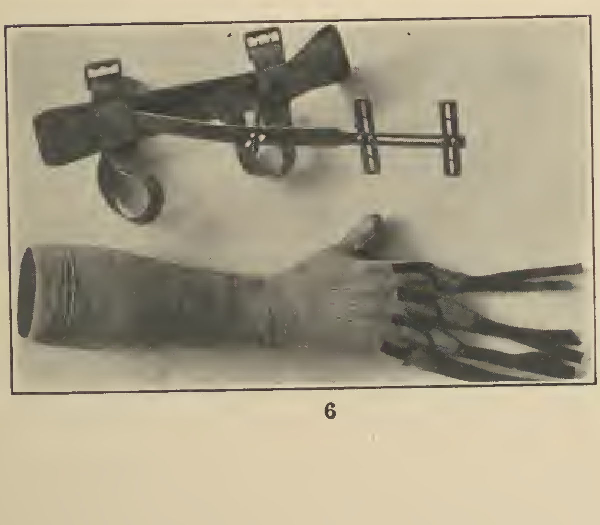

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LEGEND FOR PLATE XX

Fig. 1.—C. W. Tenosynovitic Contracture of Fourth Finger.

Fig. 2.—C. W. After Tenoplasty.

Fig. 3.—T. M. Tenosynovitic Claw-hand.

Fig. 4.—L. H. Tenosynovitic Claw-hand; Glove Traction Splint.

Figs. 5, 6.—L. H. Result of Conservative Treatment.

Fig. 7.—C. D. Tenosynovitis; Scar-bound Flexor Tendons.

Fig. 8.—C. D. After Tenoplasties

Fig. 9.—B. C. Ankylosis of Wrist Following Tenosynovitis.

Fig. 10.—B. C. After Arthrodesis of Wrist.


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in claw-hand formation with extreme hyperextension of the wrist. Of special interest are isolated burns in the thenar region. We have seen some which produced extreme adduction contracture of the thumb with pronounced flexion of end and basal phalanx.

The method found most satisfactory in dealing with extensive scar formation is that of the pedunculated flap, the so-called Italian method. The flap is taken from the skin of the abdomen or the chest as a single pedicled flap, or the double pedicled, or so-called pocket flap may be used, especially in covering a defect on the dorsum of hand and forearm.

The pedunculated flap method has been used from old Indian times. But it is more commonly known as the Italian method, since it was first mentioned and described in the book of Tagliacozzi (1546–1599), which contains an accurate description of the technic. The pedunculated flaps, simple, compound or double-faced, are extensively used in surgery of the upper extremity (J. S. Davis, Skillern). Reports by Skillern on the use of the pocket flap method are especially favorable. The double pedicled furnishes much better condition of nutrition than the single pedicled flap. Besides, by slipping the hand or forearm under the raised flap, a certain amount of fixation is secured.

Technic.—In order to secure good nutrition, a flap should not be longer than two or three times the width of the pedicle, and the position of the latter should be directed carefully by the conditions of blood supply. If possible, the flaps should follow the directions of the arteries which supply the area of skin used for the flap. Pieri, in his study on the location of skin flaps in the upper extremity, gives valuable suggestions as to the proper placing of skin incisions. Upper abdominal flaps should have a centrally located pedicle, whereas, in lower abdominal flaps, it should be located distally. It is not necessary that the flap be made extraordinarily large in order to cover the defect. An excess in size by one-half or three-fourths of an inch over the area of the defect is, in the medium-sized flaps, usually sufficient. When a skin flap becomes suffused with blood due to venous stasis, the scarification of the flap, according to Mayo's advice, is a good way to relieve the congestion. The adaptation of the flap to the defect formed by the excision of the scar should be most painstaking, and, after the flap has been placed, absolute immobilization is essential to avoid pulling and undue tension. This is best secured by a well-applied plaster cast. In the case of chest or abdominal flaps being used for the covering of defects of the forearm or hand, the cast should reach from the pelvis to the shoulders and include arm, forearm, and hand. For the suture of the flap, horsehair or fine catgut should be used. No antiseptic should be applied, but the skin should be carefully covered by strips of gutta-percha coated with sterile vaseline. As to the time when the flap should be liberated from the pedicle, the writer believes that an interval of two or three weeks is, in general, most appropriate. At any rate, the pedicle should not be cut before ten days have elapsed, and sometimes it is advisable to carry out the separation of the pedicle

gradually, in several steps. During the period of fixation in plaster, it will be necessary to dress the wound several times because of the profuse secretion. This can be done from a window in the cast or by removing the cast temporarily under precautions and having it subsequently reinforced when the dressing is done.

The writer has used the method to good advantage in cases of extension contracture of the hand.

Case Reports.—Male patient, 33 years, with bad scar from burn situated at the dorsum of the wrist. The scar prevented flexion of the wrist, completely holding the extensor tendons fixed in such a position that closure of the hand could not be accomplished. Operation was performed with the use of the Italian flap method and carried out in 2 steps, to which 2 months later an additional flap operation was added to complete the covering of the skin defect by elastic skin. Both flaps took well, leaving an entirely soft and pliable skin on the dorsum of the hand which allowed of sufficient flexion of the wrist to make a good grip possible (Plate XXII, 1, 2).

Girl, 3 years. Contracture of the wrist from dorsal scar due to burn 1½ years previously. The scar was excised and covered with a pedicled flap taken from the chest. In this case, the result was not as satisfactory because the excision of the scar on the dorsum had not been extensive enough, leaving a margin of scar tissue. The flap took well, however, and the remaining skin was pliable and soft (Plate XXII, 5, 6).

Child, 2 years. Having received, ½ year previously, a severe burn in the palm of the hand resulting in contracture of the thumb which was drawn tightly against the palm. The scar was resected and the defect covered by a flap cut from the left hypogastric region. The result was satisfactory and the thumb could be abducted.

Scar contractures of the fingers from burns were treated by pedicled flaps from the chest, in one instance, and by simple skin plasty, in another. In taking a flap from the hypogastric region to cover a defect on the volar side of the finger, one must take care not to get the flap too heavily padded with subcutaneous fat. In one case, the flap, though healing perfectly, caused considerable raising of the skin due to underlying fat, which, contrary to expectation, did not atrophy. This necessitated a secondary operation in which the resection of the subcutaneous fat was carried out. It seems that in general too much reliance is placed on subsequent atrophy of subcutaneous fat in flaps taken from the chest or the anterior abdominal wall. An abundant layer of fat is not necessary to secure the nutrition of the flap, although the latter must not be stripped too close, and must retain its layer of subcutaneous tissue. From the standpoint of cosmetics, there are certainly serious objections to the use of a flap too heavily endowed with underlying fat tissue (Plate XXII).

Scar Contractures of the Elbow.—Scars from burns in the elbow in the cubital fold cause very resistant flexion contractures. These cases lend themselves very well to the application of the Italian flap method.

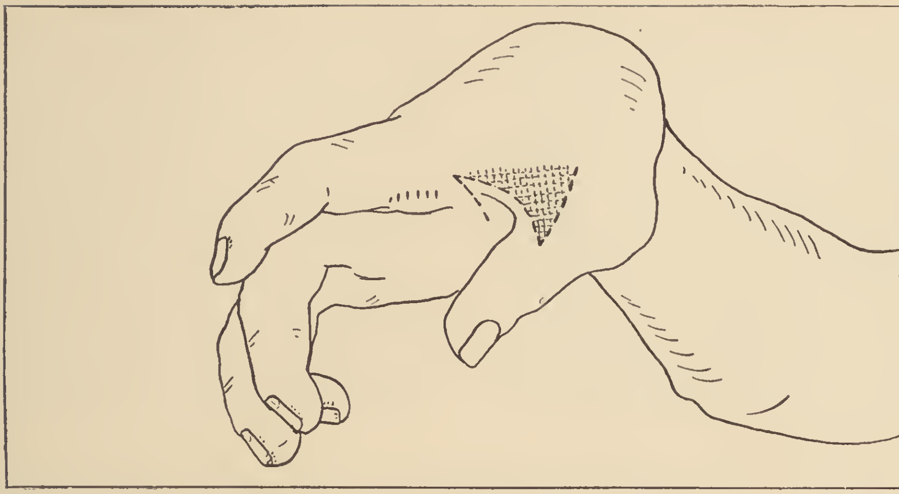
LEGEND FOR PLATE XXI

TECHNIC OF SKIN PLASTY OF CONTRACTED THUMB

FIG. 1.—INCISION.

FIG. 2.—RAISING OF FLAPS.

FIG. 3.—SUTURING OF FLAPS.



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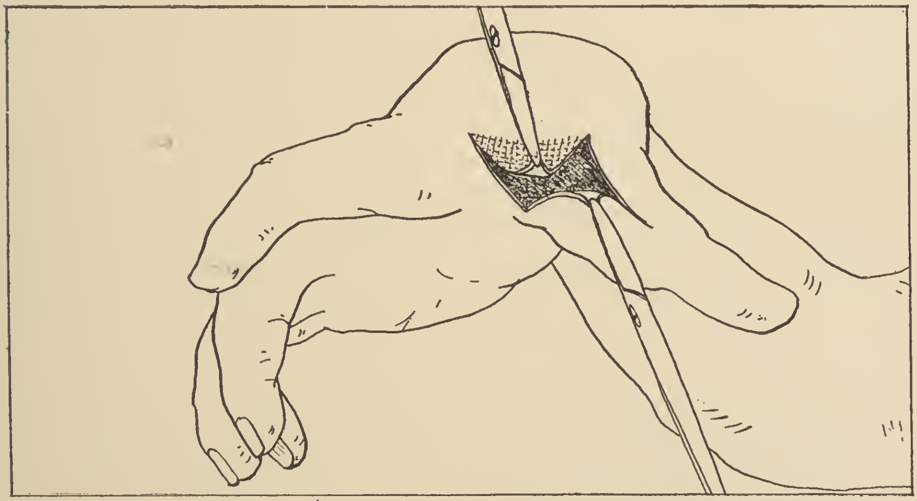

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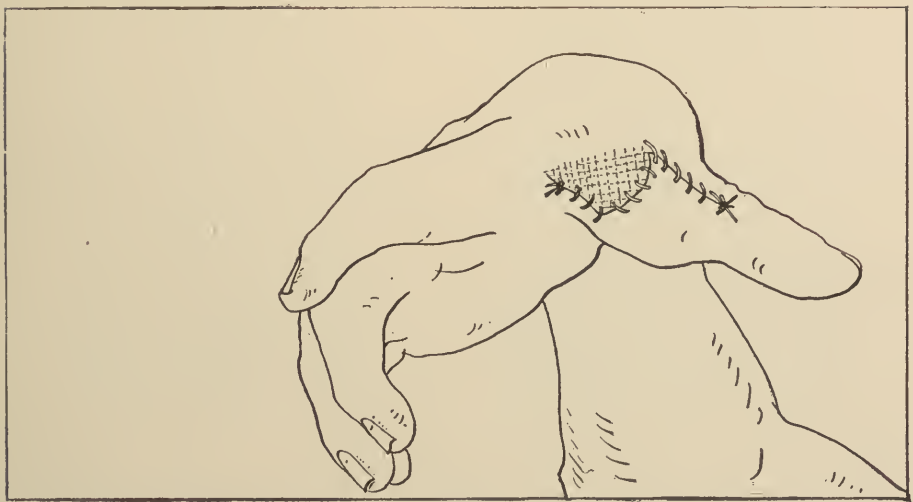

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LEGEND FOR PLATE XXII

FIG. 1.—F. J. EXTENSION CONTRACTURE OF WRIST (BURN).

FIG. 2.—F. J. AFTER ITALIAN FLAP PLASTY.

FIG. 3.—D. M. EXTENSION CONTRACTURE OF WRIST (LACERATION).

FIG. 4.—D. M. AFTER ITALIAN FLAP PLASTY.

FIG. 5.—H. G. SCAR-BOUND FLEXOR TENDONS OF WRIST.

FIG. 6.—H. G. AFTER TENDOLYSIS AND TENDON PLASTY.

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Case Report.—Woman, 26 years old, received a gasoline burn 6 months previously, followed by cicatricial contractures of the left elbow, among other severe contractures. Motion of elbow was limited to a range of flexion from 45° to 90°. The elbow could not be extended beyond the right angle. A broad flap was cut from the epigastric and upper abdominal region and placed upon the skin defect, obtained after complete excision of the scar in the elbow. The flap was cut loose from its pedicle after 21 days. Result was an increase of the extension of the elbow from 90° to 150° (Plate XVIII, 1, 2).

The pocket flap is a two-bridge flap with pedicles above and below, and is raised from the abdominal wall by two parallel incisions. The flap is held up by retractors and the hand can be slipped readily under it so that it will serve especially well to cover a defect on the dorsum of the hand. The edge of the flap is sutured to the edges of the defect, the best suture material being, according to Stiles, silkworm gut. The dressing is carried out with dry sterile gauze. Stiles allows a considerable time for the establishment of circulation between flap and hand, and he divides the pedicles not less than twenty-three days after the first operation.

Some difficulty is sometimes encountered in drawing together the abdominal skin when a large abdominal flap is cut, and the defect on the abdominal wall is to be covered. In order to avoid undue tension in such cases, it is sometimes advisable to make parallel incisions some distance from the edge of the flap incision so that the skin can be mobilized with greater ease. Dr. Christian Fenger of Chicago was the first who used pedunculated flaps in injuries of the hand.

NEOPLASTY OF THUMB AND FINGERS

The Neoplasty of the Thumb.—In case of partial or total loss of the thumb, several methods of substitution are possible. They may be divided into: (1) methods in which the new thumb is formed from tissues taken from other parts of the body, the method of thumb plasty proper; (2) methods in which the thumb is substituted by exchange of other fingers, Nicoladoni's finger exchange method; and (3) by methods in which the metacarpal is used for the formation of a finger, the Italian phalangization method.

Material for the new-formed thumb can be obtained most easily by a flap from the abdominal wall into which a bony transplant is inserted taken from the tibia or the ribs; a new digitlike formation is first made, properly pedicled so as to receive ample nutrition; this structure is then implanted into a properly prepared base at the place of defect. A method of this kind is used by Albee, who describes it as follows:

A pedicled flap is taken from the abdominal wall and the material of bone taken either from the finger phalanges or metacarpals, if those are

available, or, if not, a bone transplant is taken from the fibula. This is inserted into the pedicled flap raised from the abdomen, in a second operative step. In a third and fourth sitting, the severance of the flap from its abdominal base is carried out.

Technic of Schepelmann.—A section of the fibula is removed and transplanted into the abdominal wall. Then, by raising the integument around it, this is gradually mobilized until there is obtained a pedicled skin flap containing the bone transplant in the center. At a third step, this pedicled flap is sutured to the properly prepared base of the mutilated or missing finger, and the position secured by plaster bandage. After ten days, a gradual separation of the pedicle from the abdominal wall is carried out. This author also made observations on the late condition of neoplastic fingers. The cases were followed up for a number of years and it was found that the bone transplant firmly united with the metacarpal of the missing finger. The circulation in the new-formed finger improved and the initial bluish discoloration of the finger gradually disappeared. Sensation of the finger developed from the skin of the host, finally including fully two-thirds of the new-formed thumb.

CASE REPORT.—This method was used by the writer in one case of congenital defect of the thumb.

R. G., 8 years. Congenital defect of the thumb with radial club-hand. Partial defect of the radius. The club-hand deformity was taken care of by previous operation. The method used for substituting the missing thumb was as follows:

A circular flap was raised from the abdominal wall with the base pointing to the side opposite to that of the defect. Into this flap, there was inserted a piece of the seventh rib, previously resected from under the flap. The skin flap was closed around the rib to form a sort of roll, and the end of the protruding rib was fastened to the metacarpal of the thumb by wire suture carried through drill holes. The free ends of the flap were then sutured to the prepared base of the missing thumb.

At the second step, the abdominal pedicle of the new-formed thumb was severed three weeks after the first operation. Up to that time, the position had been secured by plaster cast. The result obtained was a thumb shorter than had been desired, a fact which was due entirely to incomplete technic. But the patient was able to hold objects between his fingers and the new-made thumb, and had just begun to use it in the course of a persistent after treatment when he was lost sight of.

Other instances of reconstruction of the thumb by this so-called skin roll plasty from the chest are reported by Payr, Nicoladoni, Ritter, and others.

The second method is that of substitution of fingers by other fingers or by the toes. This method is ascribed first to Nicoladoni, who reported several cases. The method consists in exchange of the missing finger for one of the toes, preferably the big toe. In the first step, the scar covering the defect is resected and the base is properly prepared after dissecting the flexor and extensor tendons of the stump. Then a curved

incision is made over the metatarsophalangeal joint of the big toe, the extensor tendon is divided, and the toe dislocated in the metatarsophalangeal joint. The toe is then brought into apposition with the prepared base of the thumb, the former being attached to its original site by the structure of the plantar surface only. The capsule is now sutured to the base of the defect and the peripheral end of the extensor of the toe is united to the central end of the extensor of the thumb. The skin is closed and position secured in plaster. At the second step, after ten to eighteen days, the volar skin bridge is gradually severed and again the distal end of the flexor of the toe sutured to the central end of the flexor of the stump.

Oehlecker, Riedel, Muehsam, and others have followed this method with gratifying results.

Substitution of the thumb may also be accomplished by implantation of a finger from the other hand. An operation of this type is described by Joyce (1918), who used the ring finger of the opposite hand to substitute the missing thumb, applying a two-step method. The result of this case ranks among the best reported in the literature. He obtained a functionating, and very sightly neoplastic, thumb with good gripping power. Verrall reports transplantation of the remainder of the index finger of the same hand to the metacarpal of the missing thumb.

The third method which has been used for thumb substitution is the so-called phalangization method reported by Pieri.

In the case of loss of thumb and index finger, the isolation of the first metacarpal is carried out first, then the second metacarpal is entirely resected. This leaves a broad interdigital space between the first and third metacarpals. The isolation of the second metacarpal is carried out from a curved flap and the bone is disarticulated at its base. In isolation of the first metacarpal, it is important that all muscles of the thenar eminence be left intact. The simultaneous removal of the second metacarpal is carried out in order to obtain sufficient skin to cover the space completely on both the ulnar and radial side of the cleft. The radial artery must be properly protected from injury at the proximal ends of the first and second metacarpals where it crosses these bones to form the deep carpal arch. In two cases reported by Pieri, the function of the thumb so formed was quite satisfactory, the hand attained the faculty of gripping, and the thumb could be opposed. The conservation of the opponens pollicis allows of some inward rotation, adduction, and opposition of the metacarpal. Some pure adduction was also possible in spite of the fact that the adductor pollicis had been sacrificed. This was due to the concerted action of the long flexor and long extensor of the thumb. It should be mentioned that, in 1914, Lyle already had reported a case in which the loss of the thumb was met by a method similar to what was later reported by Pieri. Incision of the soft parts was made in the first intermetacarpal space with best possible preservation of the thenar muscles. The skin of the dorsum

of the hand was carried around the second metacarpal and united to the palmar skin. A similar procedure is reported by Wierzejewski in 1919, who split the first intermetacarpal space, preserving also the thumb muscles. His reports cover four cases: one with loss of thumb, one with loss of thumb and index finger, one with thumb, index finger, and end phalanx of third and fourth fingers lost, and one with all fingers lost except the fifth. In all these cases, phalangization of the thumb was carried out and the first patient especially, who had lost the thumb only, had an excellently functionating hand which enabled him to play the piano.

In a case of loss of all fingers except the fifth, Quetsch split the metacarpals full length to the wrist forming a two-fingered forceps with abduction power. The latter method already approaches the forcipization methods of the forearm, as described by Putti, Delitala, and Kruckenberg, applied to cases of loss of the entire hand.

It is not within the scope of this essay to go into the details of the methods which have been devised for the mobilization of stumps following amputation. But, warranted by the close relationship to orthopedic interests, there should be at least short mention made of an ingenious method known as cinematization of stumps.

In 1896, Dr. G. Vangetti, an Italian physician, turned his attention to the unfortunate condition of his countrymen who were mutilated in the Abyssinian War. Realizing that there were still intact muscles of the forearms, which were now rendered useless after amputation of the hand and forearm by being bereft of their natural levers, he conceived the idea of isolating the distal and tendinous parts of the muscle and inclosing them with a covering of skin. In this way he attempted to produce a terminal arrangement capable of voluntary contraction which, if formed into the shape of a peg or loop and attached to a specially constructed prothesis, could be made to bring about coördinate motion. This latter would be differentiated into one or two cardinal motions, possibly antagonistic to each other, so that opposition movements in a single plane could be carried out. With the outbreak of the World War, this method was further elaborated and perfected by Sauerbruch of Zurich and by a number of Italian surgeons. These were the beginnings of what is now known as kinoplastic surgery, which has received a powerful impetus from the abundant material produced by the late war. V. Putti of Bologna further developed and improved the original methods, and in 1918 he was able to report on 50 cases. His best results were obtained in arms which had been amputated either above the wrist or above the elbow.

Between these latter methods and those of phalangization of the thumb, which was mentioned before, stands the method of Kruckenberg, elaborated by Putti, Delitala and others. It is called the method of forcipization of the forearm. It consists essentially in a splitting of the forearm between radius and ulna and subsequent mobilization of the radius. A rather elaborate technic, too complicated to be mentioned in brief,

takes care of the covering of the bones with skin material. By means of systematic muscle education, an actively moving forceps or pincer arrangement is obtained which consists essentially of two big fingers like the hands of a shears, which move against each other and are capable of holding light objects such as the handle of a fork, a knife, a glass, etc., between them. It is hardly necessary to add that such a forearm, though useful, is an extremely hideous and ungainly thing, and many patients are reported as refusing the operation for cosmetic reasons.

Putti and Delitala have improved upon this method in a manner which partly meets these objections. Delitala distinguishes between a "mano-carpica" and "mano-metacarpica" according to whether the cleft is carried into the metacarpals or higher up into the carpus and above, depending upon how much of the hand has been preserved. Some forceps action can be obtained to great advantage when at least part of the metacarpus has been saved. We are referring to Kruckenberg's and Delitala's publications for the study of the details of this method.

ISCHEMIC CONTRACTURE

(Volkmann's Contracture; Ischemic Paralysis)

In 1875, R. Volkmann described a contracture occurring in the forearm and hand, which followed the use of constricting bandages or splints applied for fracture of the forearm or fractures of the humerus near the elbow joint. The condition is now generally known as Volkmann's ischemic contracture, or, better, as ischemic myositis, because the underlying condition is essentially that of an interstitial myositis. It develops under the influence of circulatory disturbances subsequent either to the fracture itself or to the constricting bandages applied later.

In order to understand the condition, one must first consider how the muscles of the forearm react to interference with their blood supply in various degrees. We know that, deprived of their oxygen supply, the muscles finally disintegrate and coagulate. A number of investigators have busied themselves with the study of the influence of ischemic conditions upon the life of the muscles. Stenson noted a paralysis of the lower extremities after ligature of the abdominal aorta. Leser and Babinski were able to obtain paralysis in rabbits by tight bandaging, but they could not obtain contractures, and, similarly, in Lossen's experiments, there appeared paralysis after six hours of constriction, only to disappear again within three months. Zur Verth reports a case of paralysis of all muscles of the forearm following the use of a rubber bandage which had been left applied for an hour and a half in order to control hemorrhage from the ulnar artery. We note that the latter report already approaches the clinical picture prevailing in cases of ischemic contracture. By various observers it has been pointed out

that the involvement of the ulnar and median nerves shares equally in the formation of the paralytic contractures. No doubt a large number of cases exist in which the nerves are directly injured, and the condition is then primarily one of peripheral paralysis. These cases we believe can be differentiated clinically from those in which the nerve injuries play no part. In fact, it has been mentioned by Volkmann himself that direct injury to the nerves, while a frequent occurrence, is not at all a necessary factor as far as this affection of the forearm muscles is concerned. The involvement of the intrinsic muscles of the hand, it is true, can be explained only by direct injury to the ulnar nerve, which, of the nerves of the forearm, is the most frequently affected (G. G. Davis).

Volkmann as well as other observers called attention to an interval of time between injury and the occurrence of paralysis. Lorenz and Webber quote cases in which ulnar paralysis appears very gradually and after many years following an elbow injury. In this connection, we may call attention to reports of so-called delayed ulnar palsy, which have been more recently brought to attention by Leriche. The explanation of this delayed ulnar palsy is that a peripheral neuritis develops some considerable time after the original injury. We felt that this condition should be mentioned in particular so as not to give room for confusion with true ischemic paralysis.

The clinical syndrome of this contracture is so characteristic that the diagnosis will rarely be missed even if not supported by the history of trauma.

In the majority of cases, the injury is located in the lower epiphysis of the humerus following a fall or a blow. The fracture of the lower epiphysis causes an extensive injury to the soft parts in the fold of the elbow with a very considerable subcutaneous hematoma. This is followed by the development of severe contractures of the wrist as well as the fingers and, in severer cases, the ultimate formation of a claw-hand deformity. The flexion contractures of fingers and wrist are very persistent and often defy all imaginable efforts to correct them. They develop in a typical sequence and, in all cases coming under the writer's observation, the stages in which the contracture appeared were as follows: first, there appeared a flexion deformity of the wrist; then, very shortly afterwards, or simultaneously with it, a flexion deformity of the fingers developed in the mid and end phalangeal joints; and, lastly, hyperextension appeared in the metacarpophalangeal joints making the claw-hand deformity complete. The flexion contracture of the wrist is most extreme in severe cases and from the viewpoint of muscle mechanics has a powerful influence upon the development of the claw-hand deformity. This has been pointed out before in the discussion of the paralytic deformities and it may be repeated that the tension upon the extensor muscle of the fingers from the hyperflexion of the wrist is such that hyperextension in the metacarpophalangeal joints is practically unavoidable even though the extensor muscles are usually not involved in the myositic changes.

There is general evidence of severe disturbances of the circulation. The skin is blue, cold, and clammy. Severe cases show atrophy of the skin and ulceration, the sores being located mostly over the knuckles of the mid phalangeal joints. Sensory disturbances are very frequent and are most noticeable in the area of distribution of the ulnar nerve.

In severe cases, the contractures are extremely rigid, especially those of the flexors of the wrist. There is a striking and very considerable atrophy of the entire forearm muscles and occasionally also of the muscles of the thenar and the intrinsic muscles of the hand. The muscles of the forearm feel hard and indurated.

The elbow is fixed in flexion due to the myositic contractures in the fold of the elbow and it is here where the induration, as a rule, is most noticeable.

Micropathology.—Comparatively few observations have been made as regards the pathological anatomy of the muscles involved. The most common feature is the increase of connective tissue within the muscles. Barnays finds the muscle fibers of unequal thickness, irregularly arranged, and many of them show vacuoles. In many places, there is an absence of the nuclei of the sarcolemma. Transverse striation is lost. Round-cell infiltration is seen abundantly and there is ample formation of young connective tissue which eventually becomes transformed into scar tissue.

This interstitial fibrosis of the muscle parenchyma has also been described by Rowlands and Powers. The muscles have a marked translucent and brown yellowish color. Muscle fibers removed from various areas show a varying amount of connective tissue. The muscle fibers are everywhere degenerated, but most markedly so where the connective tissue proliferation is most advanced. The fibers are shrunken, of wavy outline, and, for the most part, devoid of cross striation. Frequently, they are broken up in coarse granules. In areas which are less involved by the connective tissue infiltration, the muscle fibers appear more normal in structure and at times one finds intact cross striation.

From the histological observations made by the writer, it can be stated that there is a distinct interstitial as well as interfibrillar connective tissue infiltration, with entirely uniform shrinkage of the muscle fibers which are reduced to from two-thirds to one-half of their normal size. The contours show frequent interruption. It is peculiar that longitudinal striation maintains itself largely in spite of the almost universal loss of cross striation. In the tissues taken from the part most severely involved in the fibrosis, one finds almost nothing but connective tissue with a single muscle fiber here and there interspersed. The pathology of these ischemic contractures becomes more apparent in sections taken from moderately involved areas rather than from those of complete fibrosis. There can be no doubt that the pathological basis is that of interstitial myositis.

If we compare these changes with those found in old cases of infantile paralysis or in peripheral nerve lesions on the one hand, and

of polymyositis on the other, the myositic character of this lesion will be more fully appreciated. In myositis, the connective tissue infiltration with shrinkage of the individual muscle fibers is general and evenly distributed and, in this respect, quite corresponds to the picture seen in ischemic contractures.

On the other hand, in peripheral or in poliomyelitic paralysis, the histological picture of the muscle is very different. There is, in both of these conditions, a certain amount of interstitial connective tissue infiltration. But by far the most marked factor is the infiltration of fat. The muscle fibers also show a great inequality in the diameter of individual muscle cells. Some are shrunken to one-tenth of their normal size, while others present apparently normal dimensions. In traumatic peripheral paralysis, especially, the dominant feature is that of muscle degeneration, with only a moderate and secondary infiltration of connective tissue.

These histological findings ought to dispel any doubt that the ischemic contracture of Volkmann is a myositic process, which sets up a tremendous infiltration of connective tissue in the muscle substance with general induration and scarring of the muscles (Plates XXVI, XXVII, 1-4).

The condition is not as rare as might appear from the rather scarce literature on the subject. In the last ten or twelve years, more attention has been paid to this condition and the reports have become more frequent. J. J. Thomas, in 1909, published a very accurate review of the literature up to that time, collecting 107 cases. Of these, a large majority was caused apparently by constricting bandages. He found claw-hand formation in 62 cases. Pressure sores after plaster bandages were found in 79 per cent of the cases according to Alivisatos and Economos, who compiled 144 cases in the literature up to 1916. To what extent constricting bandages are responsible for the occurrence of this contracture is a matter still under discussion. Surely a large percentage of cases is brought about in this way, but one must not lose sight of the fact that a number of cases coming under observation never have been treated either by constricting bandages or by splints, the fracture often having remained undiagnosed at that time. In those cases, it must be that the pressure from the subcutaneous hematoma is in a large measure responsible for the myositic changes and the subsequent contractures. From this point of view, the question is to be considered whether one is not justified, in cases where a considerable hematoma is present, in performing an early incision to release the hematoma. This seems to be an entirely rational procedure and we believe it should be carried out more often.

Treatment—*Prophylactic.*—During the stage of the development of the deformity, it is possible to overcome the danger by timely and proper splinting. The constricting cast must be removed at once. The repair of the bone is usually already fully developed when the first sign of contractures set in.

A great many cases of ischemic contracture will respond to conservative treatment. Where the line is to be drawn between the cases which will yield to passive stretching and those which will not is difficult to determine. One may say, in general, that the contracture of the wrist is often so firm that no amount of passive manipulation will relieve the deformity unless preceded by operative methods.

The conservative treatment has made considerable progress since the general acceptance of the method of Robert Jones. The principle of this method consists in the gradual, continued stretching of the contracted joints by malleable iron splints. The wrist is first placed in extreme flexion so as to relax the flexion contracture of the fingers as much as possible. Then, by means of individual finger splints, the gradual correction of each individual finger is accomplished. When the flexion contracture of the fingers has been overcome, the contracture of the wrist is taken care of in a similar manner by correcting this deformity in steps with the aid of a malleable volar splint. Of all conservative methods applied, this seems to be the most efficient. Goldthwaite has reported very favorable results obtained by this method.

Volkmann himself advocated the stretching of the contracted tendons under anesthesia, but he was not very optimistic as to the possibilities of correction, speaking of the almost unmanageable claw-hand deformity as a feature of ischemic contracture. But since Jones' method has been more widely accepted, the reports of good results obtained by conservative means are more numerous, and—aside from Goldthwaite—Alexander, Watts, Froelich and others have recommended this method of gradual correction with individual finger splints. The value of this method seems to lie especially in the principle which holds that these contractures are to a certain extent amenable to correction, when wrist and finger deformities are taken up separately; and that, by flexing the wrist in the extreme, the fingers are relaxed. It is essentially a gradual splint correction divided into two distinct stages.

There are, however, definite limits to the efficacy of the conservative method alone. The most serious obstacle to correction is the flexion contracture of the wrist itself. In severe cases it is of such rigidity that either forcible or gradual stretching becomes out of the question; and in such cases one has to resort to operative methods.

The methods generally applied might be divided into two classes: plastic operative methods of the soft structures, and bone plasty.

Earlier operators tried incisions through the contracted muscle fibers (Drehmann). Systematic lengthening of the contracted flexor tendons was reported first by Schramm in 1904 and his results were very favorable. Other authors attempted the release of contracted muscles by edgewise incisions into the muscle, making in this way a sort of pennated muscle. A good method, reported by Aberle, deserves mention. From the common head of the flexor muscles at the ulnar epicondyle, he severs the superficial layer in a flap containing the flexor carpi radialis, palmaris longus, and flexor digitorum sublimis. The pronator teres

is left intact. After dissecting these muscles from their point of attachment, with careful preservation of their blood and nerve supply, the tendons of the flexor profundus are lengthened further distally and now the hand is fully extended. As this is done, the muscle flap pulls off from the internal epicondyle and is drawn downward. The subsequent overcorrection following this operation was carried out by means of articulated splints.

It seems to the writer that the methods applied for the release of the deformities in ischemic contractures should, above all, be simple and purposeful. If operative methods are required, and they are, probably, in a large number of the cases, they must be considered only as an initial step in the correction which takes care of obstacles insurmountable for the splint treatment alone. The method most commonly applied in the writer's series was that of tendon plasty.

A longitudinal incision is made on the volar surface from the middle of the wrist up to the middle of the forearm. On reaching the deep vaginal fascia, one is struck by the considerable thickening of this structure. The tendons of the flexor muscles are then picked out one by one. They will be found in different degrees of induration, often matted together, and identification of the individual tendons sometimes is not an easy matter. It is necessary to lengthen both flexors of the wrist, the common flexors of the fingers, and usually, also, the long flexor of the thumb.

The individual tendons can be lengthened readily by longitudinal splitting, Z-shape fashion, making the halves of the tendons glide over each other as the wrist is corrected. The ends may be sewed side to side with very fine catgut. When the tendons are taken care of, the fascial compartments should be restored as much as possible under the circumstances. At any rate, sufficient covering should be given the tendons to prevent adhesions to the subcutaneous tissue and the skin. In cases of marked pronation contracture, plastic lengthening or section of the pronator teres and pronator quadratus should be done. The first muscle can be reached easily from a median incision on the volar side of the forearm. In order to reach the pronator quadratus, one must proceed into the depths between the deep flexors of the finger and isolate this muscle which is easily recognizable by its transverse fibers (Plate XXIII, 1, 2, 3).

When the operation is completed, a plaster cast is applied in the best possible position, reaching from the basal phalanges to below the shoulder joint. The position of the hand most desired is hyperextension of the wrist, slight flexion of the metacarpophalangeal joint and extension of the phalangeal joints. In most of the severe cases, it is not possible to accomplish this position at the time of the operation. Circulatory conditions especially forbid forcible correction beyond a certain point. But it is not the object of the operation to take care of the deformity with one stroke. It must be again repeated that the operation is only the means of rendering the deformity amenable to

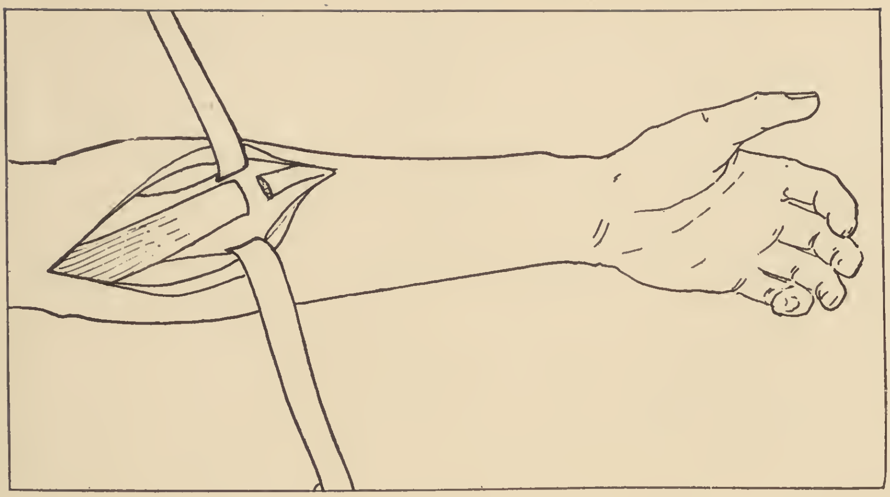
LEGEND FOR PLATE XXIII

TECHNIC OF RESECTION OF PRONATORS

FIG. 1.—EXPOSURE OF PRONATOR TERES.

FIG. 2.—RESECTION OF PRONATOR TERES.

FIG. 3.—SECTION OF PRONATOR QUADRATUS.



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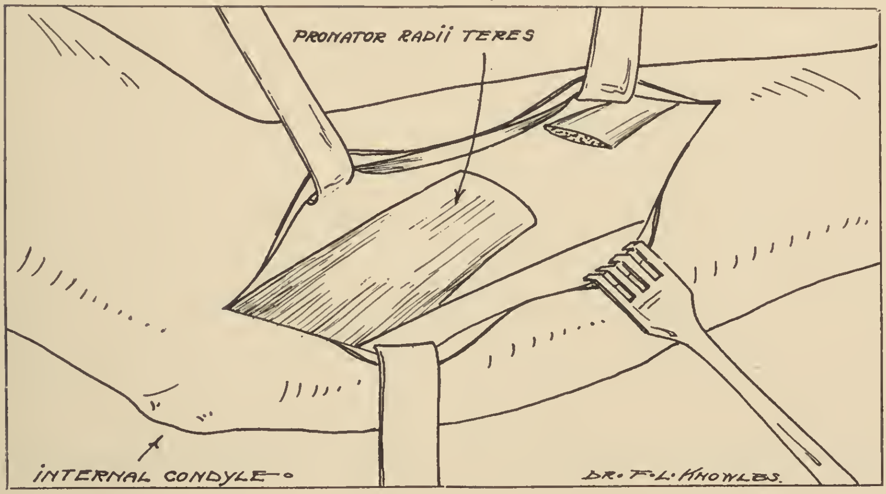

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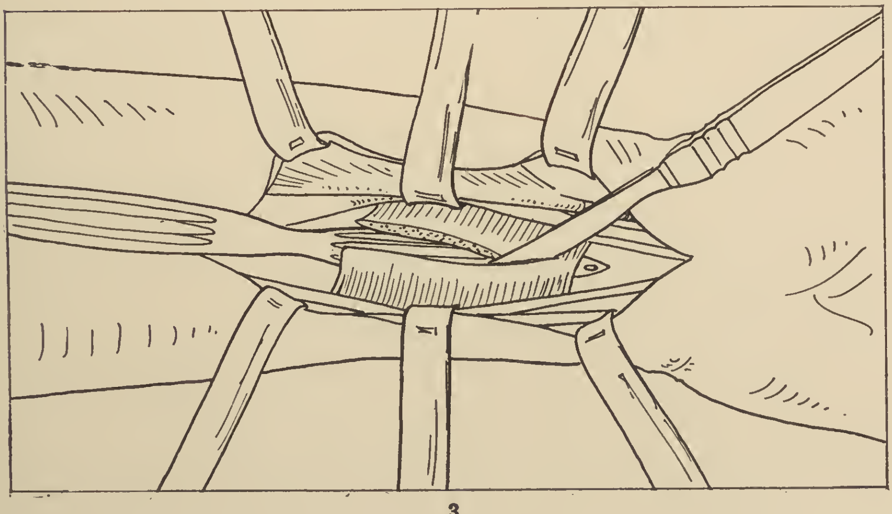

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conservative treatment. The latter is absolutely indispensable and must be carried out just as faithfully and persistently as though the case had been treated by conservative methods from the start. Opponents to plastic operations point out the lack of functional recovery which is seen even in cases in which anatomical correction has been obtained. A lack of functional result must be expected from the degree and nature of the deformity, and it should not be laid against the operation. On the other hand, during the long continued after treatment, an improvement in the function is seen which is often beyond the initial expectations. Where there is a choice, the conservative method would of course be preferable, but a large number of cases is not amenable to the conservative method alone.

There are cases of marked flexion contracture of the wrist in which the shortening of the muscles is so great that correction even by tendon lengthening seems improbable. Such a situation arises occasionally when nerves and vessels of the forearm are shortened to the extent that a forced correction would carry with it the danger of grave circulatory disturbances. Garre, in 1895, recommended the resection of the forearm bones as a method to be applied in these cases. Rowlands and Watts, Kleinschmidt and others reported favorably upon this method.

A piece of bone of suitable length is resected from the continuity of the lower third of the ulna and radius. Both ends of the bone are then drilled and pulled together by wire. This procedure shortens the forearm and allows a certain degree of correction of the flexion deformity, usually greater than could be obtained by the plastic lengthening of the tendon. It is difficult to determine at just what point the deformity becomes too extreme for tendon lengthening and requires the resection of forearm bones. One often sees cases of most severe contracture of the wrist which yield after plastic lengthening under the influence of splint treatment, and it seems that the method of bone resection should be restricted to exceptional cases. In the writer's series, the method of tendon lengthening has received the preference.

Table of Cases of Ischemic Contrature

Name	Age Duration	Trauma	Treated	Onset of Deformity	Treatment Deformity	Result	Degrees
T. N.	14 yrs. 7 yrs.	fracture elbow	splint	in splint	plastic length	good; almost normal motion; observed 2 years	mild
L. D.	9 yrs. 3 mos.	fracture elbow	splint in flex.	contracture after 6 wks.	resection pron. ter.; plastic length; flex. thumb plastic	improved in function; deformity corrected; observed two yrs.	moderate
V. T.	7 yrs. 3 mos.	supra-condyl. fracture	splint in flex.	contracture dev. after 1 month	plastic length	perfect correction; much improved function; observed 3 mos. (interrupted)	severe
H. C.	6 yrs. 3 mos.	supra-condyl. fracture	splint in flex. 6 wks.	contracture after 6 wks.	plastic length	correction good; function fair; observed 1 month (interrupted)	severe
M. H.	7 yrs. 14 mos.	supra-condyl. fracture	cast 6 wks.	after removal cast pressure sores	plastic length	correction good; function good; observed 16 mos.	severe
E. D.	6 yrs. 2 yrs.	fracture humerus	splint	after few wks.	resection pron. ter.; plastic length	correction good; function fair; observed 8 mos.	severe
R. W.	9 yrs. 4 mos.	supra-condyl. fracture	splints (tight)	after some wks. following spl.	plastic length	correction good; function good; observed 6 mos.	severe
F. P.	15 yrs. 7 yrs.	supra-condyl. fracture	splints (tight)	after several wks.	plastic length (insuff.) resection forearm bones	correction fair; function fair; observed 1 yr.	severe
O. K.	14 yrs. 6 yrs.	fracture external condyle	cast 9 days	deformity after removal cast	resection pron. ter. and pron. quadr.; plastic length	correction good; function fair; observed 6 mos.	severe
J. M.	14 yrs. 7 yrs.	supra-condyl. fracture	splint	Deformity after several wks.	plastic length	correction good; function good; observed 2 yrs.	moderate
M. G.	28 yrs. 6 yrs.	compound fracture humerus	No fixation; injury brachial artery	deformity after several days	resect. pron. ter.; plastic length	correction good; function poor; observed 1 yr.	very severe
D. P.	6 yrs. 3 mos.	supra-condyl. fracture	splint in acute flexion	deformity 2 wks. after removal of splint	plastic length	correction good; function fair; observed 1 yr.	moderate
L.	18 yrs.	dislocation	no fixation	deformity 2 wks. after dislocation	Conserv.	correction good; function good	mild
C. K.	14 yrs. 11 yrs.	birth-palsy forcible attempt at reduction of dislocation	no fixation	deformity after manipulation	Thumb flexor plasty	thumb good; further treatment refused	severe

(Plates XXIV, XXV, XXVI).

LEGEND FOR PLATE XXIV

FIG. 1.—L. D. ISCHEMIC CONTRACTURE.

FIGS. 2, 3.—L. D. AFTER TENDON LENGTHENING AND THUMB PLASTY.

FIG. 4.—J. M. ISCHEMIC CONTRACTURE.

FIG. 5.—J. M. AFTER PLASTIC LENGTHENING OF FLEXOR TENDONS.

FIG. 6.—O. K. ISCHEMIC CONTRACTURE.

FIGS. 7, 8.—O. K. AFTER TENDON PLASTY AND PRONATOR RESECTION.

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LEGEND FOR PLATE XXV

FIG. 1.—R. W. ISCHEMIC CONTRACTURE.

FIG. 2.—R. W. GLOVE TRACTION SPLINT.

FIG. 3.—R. W. RESULT OF TENDON LENGTHENING AND JONES' TREATMENT.

FIG. 4.—D. P. ISCHEMIC CONTRACTURE.

FIG. 5.—D. P. AFTER PLASTIC LENGTHENING.

FIG. 6.—M. W. ISCHEMIC CONTRACTURE.

FIG. 7.—M. W. AFTER TREATMENT.

FIG. 8.—V. T. ISCHEMIC CONTRACTURE.

FIG. 9.—V. T. AFTER TREATMENT.

PLATE XXV

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LEGEND FOR PLATE XXVI

Fig. 1.—H. C. Ischemic Contracture.

Fig. 2.—H. C. After Tendon Plasty.

Fig. 3.—M. G. Ischemic Contracture.

Fig. 4.—M. G. After Tendon Plasty and Pronator Resection.

Fig. 5.—Microphotograph of Muscle in Ischemic Contracture; Interstitial Myositis.

Fig. 6.—Microphotograph Inflammatory Myositis. Note Fibrous Infiltration.

Fig. 7.—Microphotograph Peripheral Palsy. Note Atrophy of Muscle Fibrillae.

Fig. 8.—Microphotograph of Infantile Palsy. Note Selective Atrophy of Muscle Fiber and Fat Infiltration.


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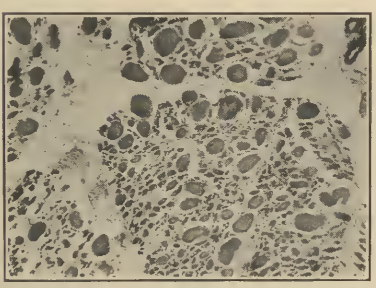
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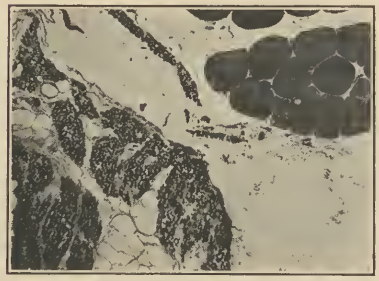
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SUMMARY

	Cases
Treated conservatively	1
Treated operatively	13
Not treated	2
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Total number of cases	16

Nature of Bone Injury

	Cases
Supracondyloid fracture	11
Fracture of external condyle	1
Fracture of forearm	1
Compound fracture of the humerus with injury to brachial artery	1
Dislocation of the elbow	1
Dislocation of the shoulder with attempt at forcible correction	1
	—
	16

Time Elapsed

Between Injury and Appearance of Contracture,
2 days to 3 months.
Between Injury and Treatment of Contracture,
1 month to 7 years.

Original Treatment of the Injury

	Cases
Constricting casts were applied	3
Constricting splints were applied	5
Nonconstricting splints were applied	4
Neither splints nor casts	4
	—
	16

Deformity

	Cases
Flexion of the wrist and pronation	7
Flexion of the wrist, pronation and claw-hand deformity	9
	—
	16

Treatment Applied

	Cases
Tendon plasty	7
Tendon plasty plus resection of pronators	3
Flexor plasty of thumb alone (further treatment refused)	1
Tendon plasty plus pronator resection, plus thumb plasty	1
Resection of forearm bones	1
Conservative treatment alone	1
	14
Not treated	2
	16

Results (Functional)

	Cases
Cured	5
Improved considerably	6
Improved moderately	3
	14

In one instance, the ischemic paralysis and contracture followed the attempt at reduction of an obstetrical dislocation of the shoulder. It was stated in the history that motion of the fingers and hand had been present before the attempt was made. This is a rather unique etiology of an ischemic contracture for which we have not found a parallel in the literature.

In another instance the damage to the circulation occurred higher up, in the upper third of the humerus, and was occasioned by a severe injury to the brachial artery from a gunshot wound.

The remainder of the cases were caused in a typical way, by injuries to the elbow and forearm bones. Only in 1 case was a dislocation of the elbow mentioned in the history, but this could not be verified at the time of examination.

In some cases it was stated that the deformity began to appear while the cast was still being worn. A remarkable fact with regard to the fixation is that, among the 15 cases, only 3 had constricting casts according to the history. But 5 more cases had tight splints applied, showing that constriction might be brought about by tight splints as well as by tight casts. On the other hand, there are 4 cases in which splints were worn but no constriction by the splints was observed and in 3 other cases there were neither casts nor splints applied. This is not in accord with the general opinion that external constriction is responsible in 80 per cent of the cases, since, in the writer's series, in only 8 out of 15 cases could external constrictions be established in

the history, and constriction by cast in only 3. It would seem, therefore, that the internal pressure from the hematoma plays a more important part in the production of the ischemic symptoms than is generally assumed. It should also be remembered that, in supracondyloid fracture of the humerus with the presence of a large hematoma, fixation at an acute angle may increase the pressure; the position must sometimes be modified to some extent in order to take care of this contingency.

A majority of the severe cases (9 out of 15) showed hyperextension in the metacarpophalangeal joints, although not all cases showing this hyperextension had an actual involvement of the intrinsic muscles of the hand with loss of function of the interossei. In fact, when the correction is completed, the interossei are generally the first ones to resume function before the flexors of the finger, except, of course, in those cases where the interossei are lost, due to involvement of the ulnar nerve. The claw-hand deformity, therefore, is not by any means attributable to the loss of the interossei function only, but more generally to the condition of the equilibrium between extensors and flexor muscles. To this hyperextension, the extreme flexion of the wrist bears a close etiological connection; the details of this syndrome have been described before.

Impairment of sensation was noted in 7 cases, 3 of which were associated with cyanosis, and 2 showed trophic ulcers. It is remarkable that the nutrition of the hand greatly improves with the correction of the deformity. Trophic ulcers heal, the cyanosis disappears and sensation becomes reëstablished to a considerable degree.

After Treatment.—Emphasis has already been laid upon the fact that the surgical treatment of this deformity is only the first stage. Intensive after treatment must follow the operation for months and even years.

After treatment should begin as early as possible after operation. Active motion may be instituted within a few days after operation, even while the limb is in the cast. As soon as feasible, the plaster cast applied at operation is replaced by a splint. This splint must meet the following requirements: the hyperextension of the wrist must be secured by a cockup arrangement; flexion of the metacarpophalangeal joints should be obtained by traction; and finally the forearm should be secured in supination by a splint so arranged that its application will force supination position. In order to meet all these requirements, a rather complicated splint would be necessary. But the extension of the wrist, the flexion in the metacarpophalangeal joint and the extension of mid and end phalangeal joints can be accomplished by combination of a cockup splint with a traction system which acts upon both the basal and end phalanges. The writer has used a so-called glove traction splint which has a volar cockup band and in which traction is applied by a double system of straps attached to a strong glove pulled over the hand. These systems of traction straps attached to the glove are arranged in two rows; one bends the basal phalanges into flexion, and the other extends

the mid and end phalanges, both systems forming an angle of about 45°. These straps can then be attached to a curved rod, the proximal end of which is fastened to the cockup splint attached to the forearm. This splint completes the correction of what deformity remains after operative interference. Massage and passive motion are given daily while this splint is worn, and the patient is early encouraged to execute active motion and to begin his regular course of muscle educational treatment (Plates XIX, 6; XX, 4; XXV, 2).

The results obtained were, as a rule, not unfavorable. Improvement obtained in 5 cases was so complete that the hand regained practically normal function. These, of course, were the milder cases of ischemic contracture, though some of them were of long standing. The other 9 cases showed improvement in various degrees; a satisfactory correction was obtained in practically all of them, but in some the flexion power of the fingers was rather poor.

The persistence with which the after treatment is carried out has a great deal to do with the final result. The function of the fingers is somtimes slow in developing. It was observed that flexion of the fingers in severe cases is first carried on by the interossei, and later the superficial and deep end flexors of the finger become more pronounced in asserting their action. In more than one-half of the cases the muscle development progressed to a point where complete closure of the hand was possible and the gripping power was good. Determined persistence in the after treatment is, as mentioned before, an absolute essential for the ultimate result. The average time of treatment is hardly less than one year.

MADELUNG'S DEFORMITY OF THE WRIST

The earliest observation of the unusual deformity of the forearm known as Madelung's deformity dates back to Dupuytren (1839), who found this condition in workers of all kinds and especially in those whose work required strain of the wrist joint as in pressers, cloth workers, washerwomen, or teamsters. Although mention of this deformity was already made by Beguin in 1825, Dupuytren's report is probably the first independent report on record. He was inclined to connect this trouble with a certain relaxation of the joint capsule and the reinforcing ligaments.

There is an anatomical description of this deformity at hand from the pen of Jean (1875), who found the lower extremity of the radius bent forward toward the vola of the hand, and the lower extremity of the ulna projected into the dorsum.

In 1878, there appeared the description of this disease by Madelung, which has given the name to this type of deformity. Madelung also lays stress upon the lower bend of the radius which causes the hand to be deflected toward the vola and the lower end of the ulna to become

distinctly prominent in the dorsum of the hand. The anteroposterior diameter of the hand appears increased and there is sometimes a slight lateral deviation. The flexor tendons, especially the flexor carpi radialis and the flexor pollicis longus, are distinctly prominent. No abnormal mobility is noted between the radius and the hand. There is an impairment of the dorsiflexion of the hand, whereas the volar flexion is usually normal or even increased. Occasionally one finds a great deal of tenderness over the wrist, but distinct pressure points are rare. Madelung was able to report on 12 cases, of which 9 were unilateral. He also noticed the preponderance of female patients over male patients, the former being twice as numerous in his collection as the latter.

In Madelung's series, the disease developed insidiously and slowly between the thirteenth year in the youngest, and the twenty-third year in the oldest of his cases. Speculation has been rife as to the etiology of this condition. Among 85 cases mentioned by Estor, there were 11 hereditary instances, and in one group of Guepin, 15 members of one family are mentioned. Feré mentions a case of mother and 2 daughters; Jagot—heredity in 3 generations. Of Estor's 85 cases in the literature, there were 10 observations of traumatism (Malgaigne, Madelung, Duplay, Redard, Kirmisson, and others). In 17 of the 85 cases of Estor, occupational strain is mentioned. Finally, mention of rickets as a contributing or etiological factor is made by Duplay, Delbet and Feré, and others.

The prominent pathological feature of this deformity is a disturbance of growth in the lower end of the radius. It seems that this transformation of the bone is accompanied by pain, especially noticeable in the formative stage of the deformity. Later, pain disappears and the patients are again able to take up their work. The curving of the radius is sometimes uniform and distributed over its entire length instead of involving the lower end only, as in typical cases. The scaphoid and semilunar are not dislocated but retain their normal relationship to the radius except for the change of direction which is brought about by the forward bend of the lower end of the radius.

There is, however, a change in the relation between the ulna and the carpal bones. This is due to the fact that the ulna, not following the forward incurvation of the radius, becomes dorsally displaced, so that there is a secondary dislocation in the ulnotriquetral articulation. Such displacement of the ulna is by no means confined to Madelung's deformity alone. In arthritic hands, in which there is a strong flexion contracture of the wrist, dorsal displacement of the ulna is often observed. It is due to the fact that a forward bend of the radius developing in arthritic conditions causes a volar deflection of the hand, leaving the ulna behind in its original position. Some authors distinguish between the true Madelung's deformity and the so-called radius carvus; in the latter type the bend involves the entire length of the bone, in the former, the distal portion only.

A complete review of the literature up to 1909 is contained in an

article by Stetten, covering 64 cases and eliminating carefully those about which there is doubt as to their identity. Of these, the radius was bent forward in 62 cases. In 2 cases, there was a bend of the radius backward so that a sort of silverfork deformity existed similar to that observed in Colles' fracture. One of these cases was reported by Kirmisson in a nineteen-year-old girl who showed both backward and ulnar displacement of the radius. The same deformity was noted by Stetten in a girl of twelve. In a great number of these cases, the forward deflection is located in the epiphyseal end, but the bend is accentuated besides by an additional curving of the entire bone. Certain changes in the carpal bones are also seen in the X-ray picture. Instead of forming an arch as in the normal hand, the bones of the first carpal row form an acute angle, with the semilunar at the apex. As a rule, the relations between scaphoid, semilunar, and radius remain normal. The cuneiform, however, loses its connection with the triangular cartilage due to the fact, already mentioned, that the ulna does not take part in the forward bend but remains in its normal position.

The deformity is overwhelmingly bilateral, 43 bilateral to 20 unilateral, in the cases of Stetten. With regard to sex, it is much more frequent in females than in males, though the ratios given vary between 2 to 1 and 7 to 1.

Pain is usually the first feature which calls attention to the trouble. It appears gradually and insidiously, as does the deformity itself. Pain usually appears upon exertion and is most marked during the formative stage of the deformity. As the latter becomes more firmly established, the pain gradually disappears.

Madelung's deformity is essentially one of the growing age, the youngest patient on record being eight, and the oldest twenty-five years. At this time there is an increase of the normal growing activity of the epiphyseal cartilage. Hereditary, traumatic, and occupational influences have already been mentioned. The disease is never congenital. While it is now believed that the immediate factor is that of disturbance of growth in the lower end of the radius, a relaxation of the capsule and ligaments as the cause of deformity was assumed by Dupuytren himself. From this point of view, late rickets may be considered as a factor and Duplay calls it a rachitic curvature of the inferior extremity of the radius. However this may be, this much seems to be certain, that there is constant and definite disturbance of growth in the lower end of the radius which, with the aid of the pull of the flexor muscles of the wrist, brings about this deformity.

The average time for the full development of this deformity is three years. Next to pain, weakness, fatigue, and limitation of motion in certain directions are the principal symptoms. In the common type, in which there is forward bend of the radius, extension is naturally limited, while in the exceptional cases, with backward bend of the radius, there is limitation of flexion. There is also a slight restriction of pronation and supination.

In some cases it is possible to reduce the ulna back to the level of the radius, although in the majority of cases it is not, and even where one can reduce the ulna, it cannot be maintained in this position and always tends to regain its normal place dorsally.

From the viewpoint of differential diagnosis, only a few conditions must be considered. Colles' fracture with forward displacement of the hand may easily be excluded from the history and the X-ray findings. In some cases, arthritic conditions of the hand may come into consideration, especially since the latter are also able to produce a backward dislocation of the ulna. Here again the history and the absence of involvement of other joints will bring about the decision.

In regard to the treatment, Madelung himself did not consider any method of especial value. He pointed out that after a period varying from one-half to three years from the onset, pain and weakness disappear and the patients are able to resume their occupations. Neither braces nor plaster casts nor tenotomy of the flexors of the forearm as practiced by Webber have brought about any appreciable results.

The only method which has proved successful in advanced degrees of the deformity is that of wedge osteotomy such as carried out by Redard, or the simple osteotomy of Duplay and Kirmisson, or the oblique osteotomy as practiced by Poulson.

In considering operative interference, two groups of cases should be distinguished. In one, there is a simple turning down of the articular surface due to the bending of the lower end of the bone; in the other, the so-called radius carvus, the entire bone is bent. It seems that the first type is more benefited by osteotomy than the second.

Massage with active and passive motion should always follow operative interference and should be carried out with persistence.

Case Reports.—Girl, 12 years old. Complains of deformity in both forearms developing for the last 3 years, not accompanied by pain. Both forearms show very remarkable deformity consisting in a sharp volar bend of the lower end of radius, causing a notable shortening of the forearm. The power of the fingers is intact except for a certain weakness in flexion owing to the flexion position of the wrist. X-ray shows forward bend of the lower end of the radius, the ulna in its normal place and in a position of posterior subluxation in relation to the wrist. Osteotomy advised, but refused.

Woman, 22 years old. At the age of 12 she began to show increasing deformity of both wrists, following accident in each case. This accident was followed by a slow and gradually increasing deformity of the same type in each hand. Wrists painful at times. The X-ray showed a deformity of the wrist consisting in a volar bend of the lower end of the radius and displacement backward of the ulna, while the relation between radius and carpus was intact. The peculiar point in this case was the statement of injuries received in both wrists which did not result in fracture but after which a deformity developed gradually, with all the symptoms of Madelung's deformity.

Summary.—Madelung's deformity is characterized by a gradual development of a volar bend of the lower epiphysis of the radius during the adolescent age. It is most prevalent in women. The deformity itself is accompanied by symptoms of ache or pain, attributable to muscular and ligamentous strain. The pain disappears after the full establishment of the deformity. Heredity plays a certain part and predisposition and late rickets may be factors in the etiology of the deformity. The significance of trauma is uncertain. Milder cases require no treatment. Cases with distinct functional impairment and with a considerable and localized deformity are greatly benefited by osteotomy.

DUPUYTREN'S CONTRACTURE

The description of the first case of this deformity goes back to Astley Cooper; but it was Dupuytren in 1831, who first dissected a case of this type of contracture which thenceforth took his name.

The deformity consists in a thickening and contracture of the digital processes of the palmar fascia. The main body of the palmar fascia is affected secondarily. As a result of the thickening and contracture the fingers become more and more drawn into the palm. The flexor tendons take no part in the contracture. In extreme cases the interphalangeal joints may become partially dislocated (Block).

The contracture begins insidiously and slowly, without any apparent cause. There are no signs of inflammation, pain, or tenderness, and imperceptibly the flexion position increases. The fourth and fifth are the fingers usually involved. The flexor tendons are usually not involved in the contracture but the latter is entirely extratendinous. For this reason the extreme position of flexion of the hand does not add to the range of passive extension, but the fingers remain in their contracted position. The first finger to become involved is the ring finger, but the fifth soon follows in the contracture.

Pathology.—Microscopically the thickened palmar fascia consists of fibrous strands intermingled with cellular infiltration. In the earlier stages the skin over the thickened fascia appears normal, but later it becomes puckered and thickened, owing to the contraction of the fibers of the palmar fascia adhering to the skin.

Tubby believes that Dupuytren's contracture is nothing more than a localized fibrositis occurring in a part of the palm subject to pressure and to sudden strains and blows. He also points out the fact that the fibrous changes are associated often with the arterial hardening common to advancing years.

The inflammatory condition of the aponeurosis is expressed chiefly by increased formation of connective tissue fibers. This proliferation is most marked around the arterial sheaths and in the subendothelial layers of the capillaries. In this way there appears within the aponeurosis a proliferation and thickening of vascular and loose connective tissue

between the individual bundles or strands of the fascia. At the same time, the connective tissue slips of the plantar fascia likewise proliferate and cause an intimate adherence of the palmar fascia to the skin and subcutaneous fat.

By some (Krogius), this contracture is ascribed to developmental disturbances of the superficial palmar muscles (flexors breves manus superficiales); just as the palmar aponeurosis should be considered as a derivate of these muscles which exist in different mammals and also in the human embryo, so the new-formed tissue which causes these contractures should be considered as a derivate of embryonal rests of this muscle stratum. Such explanations appear to be of a rather conjectural nature, especially since it seems certain that the contracture is one of middle or later life and is evidently superinduced, if not caused, by continuous strain and stress.

Statistics.—Black's figures on 240 cases show that 104 cases were bilateral and 136 cases were unilateral. Of the unilateral

89 involved the right hand,
47 involved the left hand.

The statistics of Hume on 118 cases show that

40 cases were bilateral and
78 cases unilateral.

Of the unilateral

57 involved the right hand,
21 involved the left hand.

The statistics of Keene on 184 cases show that

103 cases were bilateral and
81 cases unilateral.

Of the unilateral

58 cases involved the right hand,
23 cases involved the left hand.

These figures reveal not only a preponderance of unilaterality over bilaterality but also a decided preponderance of the right hand over the left hand, the former being twice as often involved as the left in unilateral cases.

Treatment.—In the earlier stages one may try the conservative treatment consisting in extension, manipulation, massage, hot water, Bier's hyperemia and fibrolysin application. But in all advanced cases, especially in those in which flexion contracture has already developed, operative measures are necessary.

Systematic treatment by multiple tenotomies has been advised by Adams. He performs his multiple tenotomies first near the carpus, then at the metacarpophalangeal joints, and gradually severs all strands and extensions of the contracted fascia. The mechanical after treatment is begun from four to five days afterwards. All subcutaneous methods so far have failed on account of the insufficiency of the resection of the palmar fascia. The newer methods consequently all aim at complete excision of the palmar fascia.

Method of Tubby.—In 1904, this author published a method of dealing with the deformity by incision and clean dissection of all the fascia involved so that not a single part of the dense white tissue is left. A longitudinal incision is made over the most prominent portion in the palm and, if necessary, cross incisions are added. Flaps are dissected and turned back. There is some difficulty in doing this and one must avoid buttonholing the skin. Every portion of the fascia is dissected and hemorrhage arrested by pressure and hot water. Fibrolysin is poured into the open wound and thoroughly rubbed in for two minutes. The hand is put up in a malleable splint for two weeks. The author reports excellent results with this method.

The treatment advised by Hutchinson is as follows: first, the strands of contracted and thickened fascia are dissected out from a palmar incision; second, a resection of the head of the basal phalanx is performed from a semilunar incision, dorsally over the first interphalangeal joint, after division of the extensors; and finally, the extensors are re-sutured. This author is an ardent opponent of splinting because of its stiffening effect upon the joints of the affected fingers. Among his cases he found arthritis and contracture of all the joints of both hands following splinting.

In order to avoid adhesions of tendons after operative correction of the contracture, Spitzy uses injections and applications of animal fat. He first carries out the dissection of the fascia, then does the necessary tendoplasties, and finally greases the tendons with fat and injects it under the skin before the last skin suture is applied. A splint is worn for one or two days and then motion is carefully started.

One of the most thorough methods is that of Gill. It consists in transverse incision along the distal palmar crease. Through this incision a careful dissection is made of the entire palmar fascia, to or beyond the crease at the base of the thenar eminence. Distally it is carried to the web of the fingers. Buttonholing must be carefully avoided. Then the contracted fascia is excised without injury to the underlying nerves and vessels. The tendons do not require lengthening. If the first interphalangeal joints cannot be extended, the head of the basal phalanx should be resected through the dorsal incision (Hutchinson). A small, free transplant from the thigh is inserted smoothly beneath the palmar skin to prevent adhesions to the tendons.

Under the writer's observations have come 2 cases, each typical, neither of whom consented to operations.

Man of 54, editor, contracture starting with fifth finger, bilateral and symmetrical. At the time of examination the deformity was on the increase. Does no heavy manual work.

Man of 30, civil engineer, contracture starting with fourth and also involving fifth finger of right hand. Does considerable heavy manual work (Plate XXVII, 1, 2).

LEGEND FOR PLATE XXVII

Fig. 1.—J. S. Dupuytren's Contracture.

Fig. 2.—S. H. Dupuytren's Contracture.

Fig. 3.—H. B. Spastic Hemiplegia.

Fig. 4.—H. B. After Stoffel's Operation and Arthrodesis Plus Interosseous Transplantation.

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CHAPTER VI

SPASTIC PARALYSIS

The reason for the scant attention which spasticity of the upper extremity has received in orthopedic literature is, no doubt, due to the fact that it is one of the most difficult problems to handle, if not the most difficult of all. Owing to the greater complexity of the movement of the arm and hand, it is here all the more difficult to restore muscle equilibrium between the different antagonistic forces of the muscles, necessary in properly controlled and timed voluntary motion. If this is not an easy problem in the flaccid types of paralysis, it becomes much more complicated in spastic conditions where the disturbance of control lies in the upper motor neurons, so inaccessible to, and so difficult to manage by, therapeutic measures.

Among the different types of spastic paralysis, some will lend themselves more readily to orthopedic treatment than others. Some are almost wholly outside the reach of therapeutic means, either by virtue of their nature or by virtue of the degree to which spasticity is developed. But even in the most favorable groups, the treatment is difficult, laborious, and extremely time consuming. There are, nevertheless, possiblities of improvement in spastic paralysis of the upper extremity, and the matter is deserving, we believe, of more serious endeavor than it is generally accorded.

For the sake of convenience, one may distinguish three principal groups of spastic paralysis: (1) the intra-uterine form, (2) the intrapartum or birth-spastic paralysis, and (3) the acquired form. In a general way, the traumatic spastic paralysis from birth and the acquired form offer a more favorable outlook than do the intra-uterine or congenital types. The latter are generally known as Little's disease and to it belong cases of porencephaly, microcephaly, intra-uterine polioencephalitis, meningitis, cysts, etc.

The injuries received during the act of birth are mostly occasioned by the forceps, leading to laceration of the brain vessels and followed by hemorrhage, sclerosis, and, sometimes, by chronic meningitis or encephalitis.

In the acquired forms of spastic paralysis, three groups may be distinguished: (1) an epidemic polioencephalitis or encephalomeningitis; (2) meningeal hemorrhage or embolism from arteriosclerosis; and (3) syphilitic thrombosis and encephalitis. Of the first group, the paraplegic and diplegic forms usually involve the upper extremity to a lesser degree than the lower, but the hemiplegic form, of both the infectious

and hemorrhagic type, is likely to involve the upper extremity more extensively than the lower. It is especially the hemiplegic type of spastic paralysis which will be given closer attention in this chapter; first, because of the greater involvement of the upper extremity, and then because these cases yield more readily to treatment than other types, since the lesion is more localized.

The clinical syndrome of spastic paralysis of the upper extremity is so well known that a few remarks will suffice. In the shoulder the extremity is usually held in adduction and inward rotation. The elbow is held in flexion at acute angle close to the body, and the wrist as well as the phalangeal joints are in flexion. The rigidity is expressed by exaggerated reflexes, the overexcitability of the muscles, and it sometimes reaches such degrees that the normal position of the limb cannot be restored even by stretching and manipulation. The fingers and thumb are often closed so tight that the nails will dig into the flesh of the palm. In almost all cases, the rigidity relaxes during sleep and at times during waking hours, but the relaxation is only partial and is not under the control of the patient.

In contracture of the shoulder, the muscles mainly concerned are the pectorales muscles, the latissimus dorsi, the teres major, and subscapularis. Contracture in this joint is usually not extreme and some active abduction is possible except in very severe cases. In the elbow the flexion position is brought about by the spasticity of the flexors of the elbow, and also by the increased tonus of the flexors of the wrist. The contraction in the elbow joint is as a rule more marked than in the shoulder, although active flexion and extension are often possible to a moderate degree.

In the pronation contracture of the forearm, both the pronator teres and quadratus take part; the rigidity and contracture of the pronator teres is such that very soon a nutritive shortening of this muscle takes place, which makes even passive correction difficult, and active correction impossible.

At the wrist, the hand drops into a flexion position which causes the flexors of the wrist to become increasingly shortened. Active extension of the wrist is entirely impossible; even passive extension is often difficult. The finger flexors also contribute to the flexion position of the wrist and hold the fingers in strong contraction.

Occasionally one may see hyperextension of the metacarpophalangeal joints. This occurs in cases in which flexion contracture of the wrist is extreme and in which a state of tension exists in the extensors of the fingers intensive enough to bring about hyperextension in the metacarpophalangeal joints. It is not unusual to see also a flexion contracture of the thumb. The latter is turned down and crosses the palm of the hand and, when the hand is closed, the fingers cover the thumb. The musculature of the forearm shows little shrinkage. Peripheral circulation is good as a rule, except in extreme cases, where the pronounced contractures interfere with the free circulation of the extremity.

From the standpoint of prognosis, a differentiation should be made between the juvenile and adult hemiplegic forms. The juvenile forms are mostly occasioned by polioencephalitis, while those in adults have, as a rule, a circulatory basis. The juvenile forms show all degrees of spasticity, but a large percentage of them are not extreme and are amenable to different forms of orthopedic treatment.

The adult cases, especially those due to hemorrhage and embolism, are actually paralyzed to a much larger degree than is apparent at first examination, when the great rigidity of the muscles may be taken for muscle power. Especially, the extensor group in cases of long standing will be found almost entirely void of contractile power, a fact which becomes apparent after correction of the deformity has been accomplished.

The mental condition of the patient is of the greatest importance for prognosis of spastic paralysis in children, next to the degree and extension of the spasticity. Mental impairment is usually more marked in the diplegic and paraplegic types of the congenital form. In the acquired type, the mental impairment is much less prominent, although two-thirds of these cases occur within the first three years of life. Still, some degree of mental impairment or retardation is prominent in the majority of cases. According to Sachs, 50 per cent of all hemiplegic types are more or less retarded or feeble-minded, while in paraplegic and diplegic types, 70 per cent are feeble-minded and from 40 per cent to 50 per cent are idiotic.

Only a few idiotic patients are found in the acquired forms. In judging the mentality of the patient, however, it is advisable not to be led by first impressions and not to come to hasty conclusions, as all children of this type, especially those with congenital spasticity, are extremely nervous and are liable to become very much deranged mentally by the strangeness of surroundings and the excitement of the examination. It is essential to have the patient tone down and to let him get accustomed to his surroundings before judgment can be passed upon his mentality. Some of these cases show remarkable mental traits, especially a very tenacious memory.

Epilepsy is present in a great number of all forms of cerebral palsy. It is not necessarily a grave obstacle to the treatment, although it somewhat complicates the prognosis. A much greater obstacle to the treatment, which is not infrequently found in cases of spastic paralysis, is athetosis of the upper extremity. These cases, though normal mentally, are extremely hard to handle, and therapeutic measures often fail because of the impossibility of keeping the limb immobilized.

In no form of paralysis is the importance of prophylactic measures so great in preventing deformities as it is in spastic paralysis; and in no form of paralysis has it been so little used and the possibilities of prophylaxis so grossly neglected as in this very type. The measures to prevent contractures must be instituted at the earliest possible moment. This is even more urgent in spastic cases than in flaccid paralysis, where

the deformities develop more gradually and are, for a longer time, amenable to correction. In a case of polioencephalitis in a young child, for instance, the splinting must begin early and before actual contractures occur, that is, within the first week after the attack.

Splinting is to be followed by massage, passive motion, and such active motions as are possible. The efficacy of early treatment by splinting and mechanotherapy is a matter of record. Elliott and Bernstein have reported a case of twenty-one years' standing which was treated along these principles, with the result that considerable improvement was obtained, though this improvement was more marked in the lower than in the upper extremity. The possibility of recovering motor function in cases of spastic hemiplegia of long standing is further demonstrated by the article of Sheets and Wilson who reported 5 cases in which considerable improvement was obtained by methods of splinting.

For the upper extremity, the splinting must meet the following requirements: the shoulder must be held in abduction and outward rotation. For this purpose, an abduction splint of the shoulder is sufficient. As already mentioned, the adduction contracture in the shoulder usually does not attain the degree of spasticity which is present in the other joints of the extremity; however, a great deal of the spastic contraction can be saved the patient by proper and timely application of an aëroplane splint which takes care of the abduction as well as the outward rotation of the shoulder.

The flexion contracture in the elbow is usually not as rigid as the contracture in the wrist joints, but, as a rule, more rigid than the contracture in the shoulder. If the angle of flexion is suitable, one need not be especially concerned about changing this angle by means of splinting. Alternating the position, however, gives an opportunity for relaxation of the contracted muscle groups.

A most distressing deformity is the pronation contracture of the forearm. Usually this attains very marked degrees. It is followed in time by a nutritive shortening of the pronator teres which makes even the passive reduction of the contracture difficult. For the purpose of overcoming this contraction, we have used with advantage a so-called pronation splint, that is, a splint devised (by Dr. R. V. Funsten) to overcome pronation deformity. This splint consists of an inner upright running along the forearm and humerus and provided at intervals with crossbands which grip the palm of the hand, the forearm above the wrist and below the elbow, and the upper arm above the elbow and below the shoulder. The upper arm piece at first appears bent downward when the arm is in flexion, before the upper splint is applied and the forearm piece is attached with the forearm in pronation. Then, by giving the splint a half turn in the direction of supination, the upper bent-down piece of the splint can be made to swing up in the direction of the upper arm, and can there be attached by buckling crossbands over the upper arm. Experience will teach how much bending down is advisable and how much passive supination can be attained at one

time (Plate XIX, 4). The flexion deformity of the wrist is taken care of by a cockup arrangement which can very well be attached to the pronation splint, and finally, the flexion contracture of the fingers may be taken care of in a similar way by running the palmar end of the splint distally beyond the tips of the finger. For the purpose of treatment, the patient is taken out of his splints twice a day and the mechanical treatment is applied, which consists of passive motion and gentle stretching of the contracted flexor muscle, in massage, and finally in active motion. Active movements can be systematically obtained by scientific application of muscle educational treatment.

In the application of massage both the effleurage and friction may be applied. According to Oden, the former has a relaxing influence upon the musculature and promotes the peripheral circulation. The friction influences the nutrition of the muscles. To these are added the pétrissage, or kneading, and the tapotement, or the tapping of the muscles, both of which have a rather stimulating effect. Especially the two latter principal movements should be used with the greatest care and restriction, because the muscles are already in a state of increased excitability, and must not be overirritated. Milder cases yield to this type of treatment even a considerable time after the onset of the disease. The relaxation of contractures and the lessening of the hyperexcitability is especially noticeable. One question constantly arising is that of how provision is to be made to secure the continuance of the treatment for months and years, as it is necessary in most of the cases. If such treatment is left in the hands of the parents or people surrounding the patient, it is very essential that a system of instruction be established by which the parents may be able, not only to apply the treatment under supervision, but also to check up on the effect of it and to note, carefully and in time, signs of irritation or exhaustion of the muscles.

Operative Treatment.—Established spastic contractures of long standing will not yield to conservative treatment unless preceded or accompanied by certain operative measures for the relief of the contracture.

The operative treatment of spastic paralysis may be divided into two classes, according to the aim and object of interference: In the first, the treatment aims at the release of contractures. This is accomplished by tenotomies, by tenoplasties, and by methods of tenodesis or arthrodesis. In the second, the object is to restore the disturbed muscular balance of the contracted joints by operations upon the peripheral nerves or upon the spinal roots. The general opinion up to this time is preponderantly in favor of the simpler orthopedic methods followed by long-continued and painstaking after treatment.

The Operative Orthopedic Treatment—*Relief of Spastic Flexion Contractures of the Hand.*—In the release of spastic contractures of the hand, the operative technic follows essentially that used in flexion contracture of the wrist, in ischemic contracture.

A long incision is made in the middle of the volar surface of the forearm reaching beyond the wrist. From this incision all the flexor muscles of wrist and fingers are dissected and picked out one by one. Then they are lengthened by a Z-shaped tenoplasty which allows the two halves of the tendons to glide over each other until a suitable length is obtained. The tendon halves are fastened together side by side with fine catgut sutures. In the wrist, it is necessary to lengthen almost all the long flexors of the fingers, the flexors of the wrist, and also very frequently the long flexor of the thumb. When this is done, the fascial compartments covering the tendons should be reconstructed as nicely as possible, and especially should there be a smooth fascial covering over the volar side of the tendons to avoid any possibility of secondary adhesions (Plate XXIX).

The Relief of the Pronation Contracture.—Relief of pronation contracture requires the resection of the pronators, at least that of the pronator teres. The pronator teres can be reached by an oblique incision reaching from the internal condyle to the middle of the outer edge of the radius. A piece one to one and one-half inches long is resected out from the muscle near its insertion.

The pronator quadratus can be reached easily, as shown before, by incision made in the middle of the volar surface of the forearm over its distal fourth. One proceeds on the ulnar side of the flexor carpi radialis, dividing the fascia which covers the flexor muscles of the fingers. From here on, one may proceed altogether bluntly until the interosseous space is reached. The transverse fibers of the pronator quadratus become at once visible, and one now proceeds to locate the upper edge of this muscle. Here a grooved director is inserted between the posterior wall of the muscle and the interosseous membrane, and the muscle is severed over it. The interosseous nerve and vessels can be spared by using reasonable care. In severe pronation contractures, the release of the pronator quadratus by myotomy in the manner just described is necessary, while, in more moderate cases, the resection of the pronator teres may suffice (Plate XXIII, 1, 2, 3).

Tubby advises an efficient method of tendon transference for the correction of pronation contracture. An incision about eight inches long is made in the middle of the forearm over the line of the radial artery. The inner margin of the supinator longus is then defined and this muscle is bluntly separated from the flexor carpi radialis. The radial vessels and nerves are found and drawn well to one side. Then the pronator radii teres is located, the upper and lower margins of these muscles are well cleared and the tendon of insertion with some of the periosteum is detached from the bone. The flexor carpi radialis is then separated from its neighbors and its tendon is divided about one and one-half inches above the wrist. Both this muscle and the pronator radii teres are now placed on the stretch and both muscles are sutured firmly together.

The next step is the division of the interosseous membrane with a

tenotome, taking care to avoid injury to the interosseous artery and nerve. Through the space so made, the joint tendon of the flexor carpi radialis and pronator teres is brought around to the back of the radius. An aneurysm needle is then passed through the interosseous space and around the outer side of the radius and the tendon is drawn through behind the radius. In fixing the conjoined tendons, a hole is drilled through the radius from front to back. A silk ligature, which has previously been passed through the end of the conjoined tendons, is used by threading one end of it on a straight needle and passing needle and silk from front backward through the hole in the radius and also through the tendon end now lying back of it. Then the ends of the ligature are knotted and the tendon fixed in its new position.

Whitman's recommendation in flexion contracture is the implantation of the flexors of the carpus into the extensors, either around the ulnar or radial borders or through the interosseous space; but the attempt at holding the wrist in the position of hyperextension is, in spastic paralysis, a matter of rather problematical outlook, because of the rigidity of the flexor muscles. This factor is a constant source of disturbance to the equilibrium obtained by tendon transplantation, and the cases show a great tendency to draw the wrist again into the flexion position.

Considering the good functional result obtained in paralytic drop-wrist, the writer undertook to apply the method of arthrodesis of the wrist in cases of spastic flexion contracture. The technic in this case varied in no way from that adopted in paralytic drop-wrist. It is only to be added that, in spastic cases, the arthrodesis should be more thorough and the ankylosis obtained more rigid than in paralytic cases. The only cases which did not give satisfaction with this method were those of athetosis of the wrist and fingers in which sufficient immobilization could not be obtained after operation (Plate XXVIII, 1-9).

Finger Contractures.—In dealing with the flexion contractures of the fingers, the problem of flexion contractures of the thumb must be taken separately. The thumb is drawn into flexion and opposition so strongly that, upon closure of the hand, the thumb finds itself pinned under the flexed fingers. Naturally, this makes any gripping action and the grasping of objects impossible. A suggestion of Biesalski and Mayer has been used to meet this condition and was found very reliable. The operation consists essentially in applying a mechanical check to the flexors of the thumb by the use of the tendon of the extensor of the index finger.

An incision is made on the dorsum of the hand over the tendon of the extensor indicis proprius from the wrist down to the basal phalanx of the index finger. This tendon is then dissected and divided at the most distal point of the wound just beyond the base of the basal phalanx. A second incision is then made over the tendon of the extensor pollicis longus reaching from the middle of the snuffbox distally to the middle of the basal phalanx of the thumb. The tendon of the index finger is

LEGEND FOR PLATE XXVIII

Fig. 1.—A. H. Severe Spastic Paralysis, Meningo Encephalitic Type.

Fig. 2.—L. McC. Spastic Hemiplegia.

Fig. 3.—L. McC. After Tendon Lengthening and Arthrodesis of Wrist.

Fig. 4.—H. O. Spastic Hemiplegia.

Fig. 5.—H. O. After Tendon Lengthening.

Fig. 6.—H. O. After Tendon Lengthening and Resection of Pronators.

Fig. 7.—G. C. Spastic Hemiplegia.

Fig. 8.—G. C. After Arthrodesis of Wrist.

Fig. 9.—L. D. Spastic Hemiplegia. Spastic Closure of Fist.

PLATE XXVIII


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LEGEND FOR PLATE XXIX

Fig. 1.—W. E. Spastic Hemiplegia.

Fig. 2.—W. E. After Resection of Pronators and Thumb Extensor Plasty.

Fig. 3.—E. O. Spastic Hemiplegia.

Fig. 4.—E. O. After Arthrodesis of Wrist.

Fig. 5.—D. Y. Spastic Monoplegia.

Fig. 6.—D. Y. After Interosseous Transplantation of Flexor Carpi Ulnaris.

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then grasped by a forceps inserted through the radial wound and penetrating through to the wound over the index finger. The tendon of the extensor indicis is then pulled through this tunnel and brought out of the wound over the thumb so that it will lie approximated to the tendon of the extensor pollicis longus. For a distance of one to one and one-half inches the two tendons are now firmly united by suture, the thumb being held in a position of hyperextension. Both wounds are closed and the hand is dressed with the thumb hyperextended (Plates XXX, 1, 2; XXXI).

Operations on the Nervous System.—Operative procedures have been devised and recommended upon the skull and brain, upon the spinal cord, the posterior roots, and finally upon the peripheral nerves. Byrne recommends in the early surgical treatment of spastic hemiplegia decompression operations to be performed within from two to four weeks, under the following conditions: whenever there is threatening a medullary strangulation by intracranial pressure; in extradural hemorrhage, in intradural hemorrhage with cerebral compression, and in intracerebral hemorrhage. All these operations on the skull are conceived with the intention of relieving the intracranial pressure. The cases in which such pressure exists are usually well characterized by cranial symptoms of convulsions, epilepsy, and cerebral vomiting, and by findings of intracranial pressure symptoms in the background of the eye.

One of the foremost advocates of decompression operation in spastic paralysis is W. Sharpe who reports 236 cases operated on. Among these there were 80 cases of diplegia, 38 of paraplegia, and 117 of hemiplegia. Indication for decompression operation is, according to this author, the finding of increased intracranial pressure in the eye in the form of papilledema of the background. According to his report, all cases improved with the exception of 13. Sharpe's statistics are certainly very startling but up to this time his method has found but few followers.

Foerster's Operation.—In 1908, O. Foerster described an operation in which he resected the posterior roots of the spinal nerves with the object of relieving the spasticity of the extremities. This idea is based upon the knowledge that spasticity of the extremities is caused by the immense reflex excitability of the muscles. By elimination of the sensory half of the reflex arch, it is reasoned that the tone of the muscles must be relaxed. As far as the upper extremity is concerned, the technic can briefly be described as follows: the neural arches of the three lower cervical and of the first dorsal vertebrae are laid bare by dissection and the laminectomy of these vertebrae is performed. After opening the dura, the posterior roots of the four lower cervicals and of the first dorsal spinal segments are located, and three or four of the spinal roots are resected. In the lower extremity, a similar procedure is adopted, and after laminectomy the posterior roots from the second lumbar to the second sacral nerve are resected. After resection of the posterior roots, the relaxation of the muscles is striking both according to

Foerster's own report and according to the few who have followed this method. Up to 1914, Gumbel reported 110 cases in the literature. He states that the hopes placed upon Foerster's operation have not materialized. Especially are the cases extremely few where the operation has been successfully carried out for the relief of the upper extremity. Some surgeons prefer to do this operation in two steps, the first of which consists in the laminectomy and the second in the opening of the dura and the resection of the nerve roots. It is hardly necessary to say that this operation is fraught with great danger and not an inconsiderable percentage of the patients succumb to shock immediately after operation. Among the contra-indications for this operation are idiocy, athetosis, and epilepsy. But few cases of spasticity of the upper extremity lend themselves to this operation. It must be borne in mind that the method in itself is not as reliable in results as was first believed. Following the immediate relaxation of the muscle, there is soon, usually within a few days, a gradual increase of the muscle tone, which, however, does not reach the degree of spasticity present before the operation. It should be pointed out that the originator of the method himself lays the greatest stress upon the mechanical after treatment, without which no operation for spastic paralysis seems to be of any value.

A much less dangerous method of dealing operatively with spastic paralysis is that advocated by A. Stoffel. His method is one of selective and partial resection of certain nerve bundles out of the complex of a motor or mixed peripheral nerve. The method is based physiologically upon the weakening of the contracted muscles by partially depriving them of their normal nerve supply and restoring in this manner the balance between the contracted flexors and the relaxed and overextended extensor muscles. Before considering the details of this method, a reference should be made to certain points of biopathological nature. It is to be considered whether there is, in spastic paralysis, an absolute paralysis of the apparently inactive extensor group or whether the paralysis of the extensors appears secondary with the increased contracture of the flexors. It seems from clinical observation, at least of certain groups of spastic cases, that the damage to the extensor muscle is not absolute at the time the paralysis develops but that it becomes more and more extensive as the deformity increases. This is brought out definitely by the fact that the muscle power of the extensors can be preserved by preventing contracture in a manner entirely analogous to that which is found in infantile paralysis. In fact, the principal argument which makes for the early application of methods of splinting is the preservation of the weakened extensor muscles in spastic paralysis. According to Stoffel, the primary condition of the paralysis only relatively and partially lowers the function of these muscles which, by a systematic training and especially by prevention of the deformity, may regain a considerable part of their activity. Stoffel's operation is directed toward the elimination of the hypertonus of the contracted muscle groups and toward the restoration of equilibrium. In order to

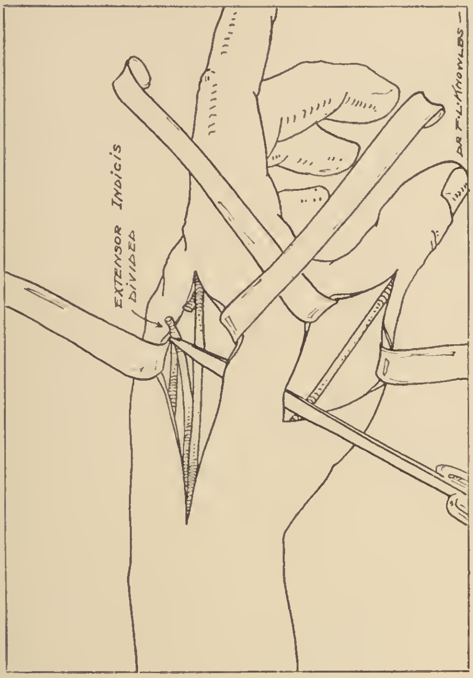
LEGEND FOR PLATE XXX

Fig. 1.—Technic of Thumb Extensor Plasty. Exposure of Tendons of Extensor Indicis and Extensor Longus Pollicis from Two Incisions.

Fig. 2.—Suture of Extensor Indicis Tendon to Extensor Longus Pollicis.

Fig. 3.—Trick Motion: Supination by Extension of Elbow; Pronation by Flexion of Elbow.

Fig. 4.—Trick Motion: Extension of Fingers by Flexion of Wrist; Flexion of Fingers by Extension of Wrist.


EXTENSOR INDICIS
DIVIDED

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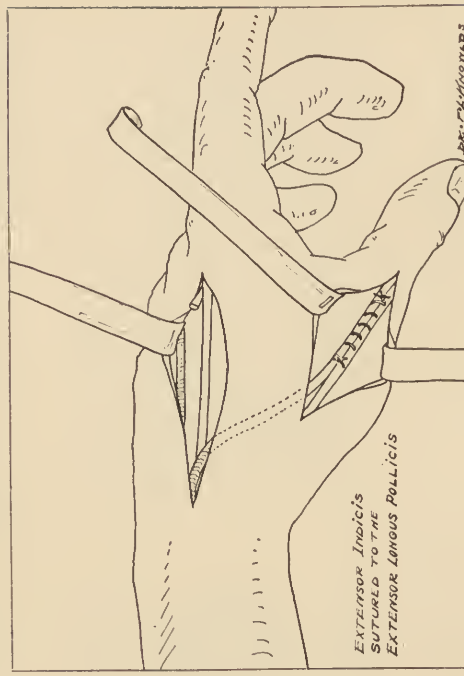
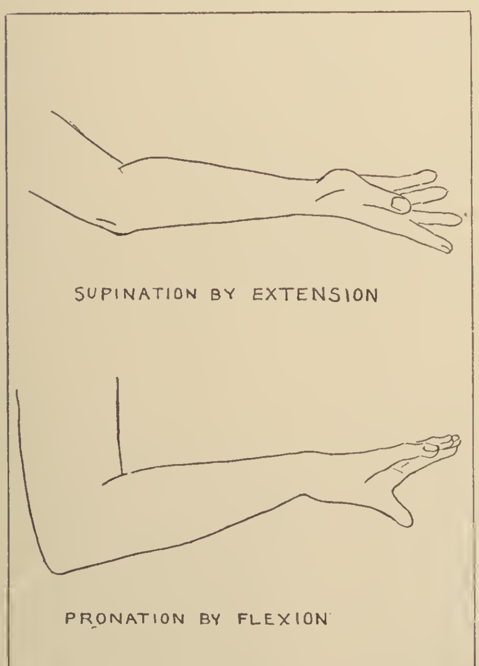
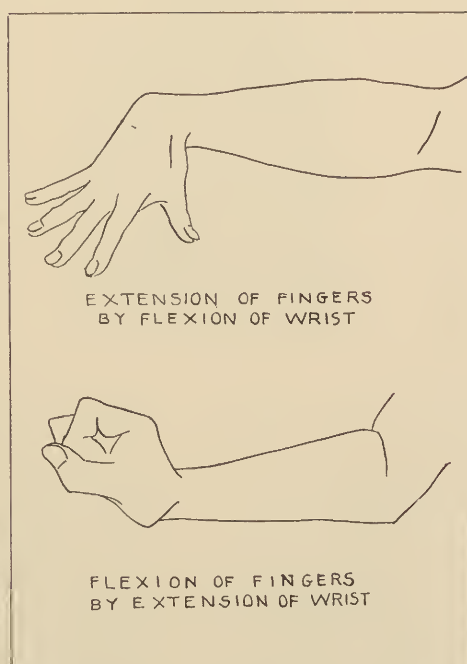

EXTENSOR INDICIS
SUTURED TO THE
EXTENSOR LONGUS POLLICIS

2


SUPINATION BY EXTENSION
PRONATION BY FLEXION

3


EXTENSION OF FINGERS
BY FLEXION OF WRIST
FLEXION OF FINGERS
BY EXTENSION OF WRIST

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LEGEND FOR PLATE XXXI

Fig. 1.—L. M. Spastic Contracture of Hand.

Fig. 2.—L. M. After Tendon Lengthening.

Fig. 3.—L. M. Spastic Fist Closure.

Fig. 4.—L. M. After Additional Thumb Extensor Plasty.

Fig. 5.—A. R. Showing Technic of Thumb Extensor Plasty.

Fig. 6.—D. G. Spastic Monoplegia.

Fig. 7.—D. G. After Thumb Extensor Plasty.

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give practical application to this reasoning, it is, above all, necessary that one should be able to identify in the peripheral nerves, at any given level, the different bundles of nerve fibers which supply a particular group of muscles. In other words, a knowledge of the topographical anatomy of the cross section of the nerve is necessary. Stoffel's own careful investigations have added considerably to this anatomical knowledge of the peripheral nerves, to which additional contributions have been made by Pieri and Riquier, and others. Pieri and Riquier, who have taken up the study of topographical anatomy of the ulnar nerve, find the bundles for the flexor carpi ulnaris and for the deep flexors of the two ulnar fingers situated near the inner surface, while those for the adductor pollicis are near the dorsal surface and those for the hypothenar and the interossei near the lateral surface of the nerve. Near the ventral surface, there are situated the sensory fibers. These findings corroborate, in general, those of Stoffel:

Musculospiral Nerve.—At the level of the two epicondyles, Stoffel finds in the musculospiral nerve on cross section the following areas:

A palmar bundle containing fibers to the superficial branch of the musculospiral.

A palmar external bundle of fibers to the supinator longus.

An external bundle of fibers to the extensors of the wrist.

A dorsal bundle of fibers to the deep muscle branches.

And, finally, an internal bundle of fibers to the superficial sensory branches.

In the course around the humerus upward, the fibers of the musculospiral nerve become rearranged so that the superficial branch is now antero-internal while the deep branches lie dorsally and externally. In the axilla, the nerves to the supinator longus and to the radial extensors of the wrist lie on the dorsal aspect of the nerve, while the fibers to the deep branches and those to the supinator brevis are antero-internal.

Median Nerve.—At the level of the middle of the upper arm, the following areas can be distinguished in cross section:

A palmar external bundle with fibers to the palmaris longus, flexor carpi radialis and pronator radii teres.

A dorso-internal bundle with fibers to the flexor sublimis digitorum.

A dorsal bundle with fibers to the flexor profundus digitorum.

A palmar internal bundle with fibers to the thenar muscles.

The fibers for the pronator teres, the flexor carpi radialis and palmaris longus lie anteriorly. The fibers for the flexor profundus, flexor pollicis longus, and pronator quadratus form a stout bundle which can be traced up to the middle of the upper arm running in the posterior part of the nerve. The nerves for the flexors of the fingers run in the internal and postero-internal parts of the median nerve in the upper arm.

The Ulnar Nerve.—The bundle supplying the flexor profundus lies in the internal and posterior part of the nerve at the level of the condyles while higher up this position changes to a postero-external. We have

then, in the middle of the upper arm, in the postero-external part of this nerve, the fibers for the flexor carpi ulnaris, flexor profundus digitorum, the hypothenar muscles, and the intrinsic muscles of the hand.

Upon such careful anatomical investigations, the hope may be based that a selective resection of nerve fibers may be carried out intelligently, especially if the identity of the nerve bundles is verified at operation by the faradic current. But there is still the problem of estimating the proper amount of resection necessary to establish the desired equilibrium between the muscles. According to Stoffel, it is possible to measure out the nerve supply necessary to maintain equilibrium between the extended and the hypertonic muscles, but it will readily be seen that, even with topographical knowledge as a basis and the faradic test as an aid, such distribution of nerve supply can be only approximately correct. The extreme subtleness of the equilibrium as it prevails, especially in the upper extremity, is of course beyond the reach of accurate dosage. But after all, this method furnishes a rational basis for the relief of contractures and one must consider that the inaccuracy of this method is not materially greater than that which exists in tendon operations where the equilibrium is also disturbed in a measure which is not entirely estimable. A. B. Gill reported on 35 cases of Stoffel's operation carried out on the popliteal, the sciatic, the obturator, and also the median nerve, of which latter there are 5 cases cited. This author and others suggest the transplantation of the separated nerve bundles into the extensor group instead of resecting them, thereby deflecting the surplus of innervation to the weaker muscle group. We believe, however, that such a matter is open to serious objection on the ground that the additional nerve supply to already supplied muscles (extensors), the so-called hyperneurotization, is extremely problematical. In his experiments, the writer was unable to produce hyperneurotization. Stoffel's own statistics embrace 12 cases among which there were 6 resections of the median nerve for pronator contraction of the forearm.

In the writer's series of spastic paralysis of the upper extremity, 3 cases were operated following Stoffel's method.

Case Reports.—J. J. H., 54 years. Spastic hemiplegia following cerebral hemorrhage of 8 years' standing. The patient suffered from severe spastic contractures of the right shoulder, elbow, wrist and fingers, the fingers being shut so tight that they could be opened only with the greatest difficulty. Technic of operation was as follows:

Exposure of the median and ulnar nerve. Dissociation of the fibers by the faradic needle as follows:

1. Ulnar nerve: dissociation of sensory and motor fibers; of the motor fibers two-thirds were resected.

2. Dissociation of the median nerve, motor and sensory fibers. Isolation of the flexors of the wrist from the flexors of the fingers. Resection of one-half of the nerve supply of the finger flexors.

The immediate result was perfect relaxation of the wrist and fingers but no active motion. The patient, however, stated that he had better

LEGEND FOR PLATE XXXII

FIG. 1.—M. S. SPASTIC HEMIPLEGIA; POLIENCEPHALITIS.

FIG. 2.—M. S. AFTER STOFFEL'S OPERATION.

FIG. 3.—T. M. SPASTIC HEMIPLEGIA; ENCEPHALOMENINGITIS.

FIG. 4.—T. M. AFTER SPLINT AND MUSCLE EDUCATIONAL TREATMENT.

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feeling in the hand and that he felt much more comfortable on being freed from the sensation of rigidity and contracture. After a period of from 2 to 3 months, slight active motion of the flexors began to appear, which at the time of this writing (6 months later) is still improving. There is, however, no sign of activity of the extensor muscles of either the hand or the fingers. The after treatment of the patient consisted in massage and such exercises as he is able to perform, and the hand is held in a glove splint fixed with elastic dorsal straps.

M. S., 15 years. Spastic hemiplegia following polioencephalitis 7 years ago. The residual condition was that of spastic contracture of the elbow, pronation contracture and flexion contracture of the wrist and fingers. The median nerve was dissected in its lower half of the humerus and one-half of the nerve was resected without preceding dissociation. The immediate result of the operation was a release of the contracture. The patient was observed for 2 months only and no information could be obtained later. During this time, only very slight active flexion motion appeared (Plate XXXII, 3, 4).

H. B. 27 years old. Spastic hemiplegia of the right side following polioencephalitis 3 years ago. The condition was that of flexion contracture in the elbow, pronation in the forearm and severe flexion contractures in wrist and fingers. Operation: The ulnar nerve was dissected and its fibers dissociated into sensory bundles, the bundles for the intrinsic muscles of the hand, and the bundles for the ulnar flexor of the wrist and the flexors of the ulnar fingers. Of the latter, ⅓ was resected. The median nerve was exposed and split up into bundles which were also dissociated by faradic current into sensory fibers, fibers for the flexors of the wrist, fibers for the flexors of the fingers, fibers for the thenar muscles. Of the flexors of the fingers, approximately ⅓ was resected.

In addition to these, the following operation was performed: arthrodesis of the wrist; muscle transference of: flexor carpi ulnaris through the interosseous route to the extensors of the fingers; flexor carpi radialis around the lower end of the radius to the extensors of the thumb.

The immediate result of the operation was complete relaxation of all contractures of fingers and wrist; within 3 days after operation slight flexion motion began to appear, first in the 4th and 5th fingers, later in the 3d and 2d finger and thumb. Very slight extension motion was noted 2 weeks after operation. The patient at the time of this writing, 2 months after operation, still under observation, is steadily improving (Plate XXVII, 3, 4).

A summary of the 3 cases reported permits the statement that the true condition of the extensor muscles seems to become apparent only after complete relaxation has been permanently established. Often the correction of the deformity alone is an advantage to the patient in that it improves the sensation and abolishes the annoying state of contracture. It seems quite probable that, especially in cases of a polioencephalitic character in which the nerve destruction is not so complete, consider-

able results may be gained by this method. It is further possible that the method may be combined to advantage with methods of arthrodesis of the wrist and also with methods of tendon transplantation.

Another operative method applied in spastic paralysis is that of temporarily paralyzing the contracted muscles by the injection of 60

Table of Cases of Spastic Paralysis Treated by Operations

Name	Age	Diagnosis	Onset	Treatment	Result of Operation
H. O.	11 years	sp. hem.	polioenc.	arthrod. wrist	good
V. P.	5 years	sp. hem.	polioenc.	thumb plasty	good
J. R.	7 years	sp. hem.	polioenc.	arthrod. wrist.	good
R. A.	8 years	sp. hem.	cong. epil.	thumb plasty	good
D. Y.	9 years	sp. hem.	polio. typh.	tendon transpl.	poor
L. M.	15 years	sp. hem.	polioenc.	flexor plasty	fair
E. F.	9 years	sp. hem.	polioenc.	thumb plasty	good
L. M. C.	8 years	sp. hem.	polioenc.	tenoplasty	poor
				arthrodesis wrist	good
				tendon transpl.	poor
C. G.	40 years	sp. hem.	luet. throm.	resect. pro. ter.	fair
G. C.	6 years	sp. hem.	polioenc.	arthrod. wrist	good
M. M.	14 years	sp. hem.	cong.	tenoplasty and arthrod. wrist	good
S. H.	7 years	sp. hem.	polioenc.	pron. transpl.	fair
A. K.	11 years	sp. monopl.	epil.	arthrod. wrist	poor
J. B.	8 years	sp. monopl.	cong.	tenoplasty wrist	fair
				thumb plasty	good
M. H.	7 years	sp. hem.	polioenc.	tenoplasty	fair
D. D.	13 years	sp. hem.	polioenc.	res. pro. ter.	good
M S.	15 years	sp. hem.	polioenc.	Stoffel's op.	fair
J. H.	54 years	sp. hem.	cer. hem.	Stoffel's op.	poor
A. K.	11 years	sp. hem.	polioenc. diphth.	arthrod. wrist	poor
E. O.	15 years	sp. hem.	cong.	flexor plasty	good
				arthrod. wrist	good
D. G.	10 years	sp. monopl.	Men. enc.	thumb plasty	good
T. G.	6 years	sp. hem.	polioenc.	arthrod. wrist	good
I. M.	14 years	sp. hem.	polioenc.	arthrod. wrist	good
L. F.	7 years	sp. hem.	convulsions, enceph.	arthrod. wrist	good
R. N.	7 years	sp. hem.	little	arthrod. wrist	good
L. D.	3 years	sp. hem.	polioenc.	thumb plasty	good
M. S.	42 years	sp. monopl.	mening.	flexor plasty	fair
S. E.	4 years	sp. hem.	polioenc.	flexor plasty	poor
				thumb plasty	fair
A. H.	5 years	sp. hem.	Little's d.	res. pro. ter.	fair
H. B.	25 years	sp. hem.	cerebr. hem.	Stoffel's oper.	good

per cent alcohol into the nerve sheath. This method was advocated by Allison, who reports that the immediate results of this operation are satisfactory. A relaxation appears after operation but, as recovery takes place, the contractures reappear again and the method does not seem to be productive of permanent results.

The writer's own series embraces 60 cases, of which 45 were treated. Of these cases, 34 were of the hemiplegic type, 6 of the diplegic type, and 5 of the monoplegic type.

CAUSES.—The paralysis was due to polioencephalitis or meningo-encephalitis in 25 cases, to congenital defects in 10 cases.

	Cases
Luetic meningitis or luetic endarteritis	2
Cerebral hemorrhage	1
Polioencephalitis following diphtheria	1
Polioencephalitis following typhoid	2
Meningitis	4
Birth trauma and instrumental delivery	2
Premature birth	1

MENTALITY.—The mentality in the 45 cases treated was as follows:

	Cases
Normal	32
Subnormal, ranging from slight mental impariment to idiocy	13
Convulsions and epilepsy	8

DISTRIBUTION OF CONTRACTURES.

	Cases
Flexion contracture of the wrist	31
Pronation contracture	25
Flexion contracture of the elbow	23
Adduction contracture of the shoulder	5
Flexion contracture of the thumb	8
Supination contracture of the forearm (congenital)	1

OPERATIONS PERFORMED.

	Cases
Arthrodesis of the wrist	12
Tendon transplantation	4
Extensor plasty of the thumb	10
Tendon lengthening and tenoplasty	7
Resection of pronator teres	4
Stoffel's operation	3

The results of arthrodesis of the wrist were uniformly good, the position of the hand being secured and its function otherwise depending upon the state of the flexor muscles.

An operation of equal reliability is the extensor plasty of the thumb, that is, Mayer's thumb check operation for flexion contracture of the thumb.

Postoperative After Treatment.—After arthrodesis of the wrist, in spastic paralysis, the cast should remain not less than two or three months, preferably three months, because of the greater length of time necessary to secure complete stability where the muscle tension is liable to interfere with the position. During the cast fixation, the fingers may be exercised actively and passively. After removal of the cast, a cockup splint is provided and massage treatment begun. In the after treatment following flexor plasty, an anterior or posterior splint may be used and if an extensor plasty of the thumb has been done, or if the thumb shows a tendency to contraction, it must be held well out in extension for a period of two or three months. In several cases, the extension of the thumb was lost because of the fact that splinting had been abandoned too soon. For the maintenance of the supination position in cases of pronation contracture, with or without resection of the pronators, a so-called pronation splint, which has been described before, is used.

The most potent factor in accomplishing final results is a persistent and untiring after treatment which must be carried out for a period of months and years. This after treatment begins, practically, within a few days after the operation with splinting and active motion to which, later, massage and passive motion are added. Muscle educational treatment also plays an important part in the after treatment.

It is in the course of the after treatment that one usually succeeds in developing substitutionary motions where the original motion cannot be obtained. Such substitutionary motions are very useful and their development should be encouraged. One of the most important ones is the mechanism of pronation and supination in pronation contracture. After the correction of the pronation contracture has been obtained by operation or by splint, the patient must learn to carry out pronation and supination by the original muscle, if he is able to. If not, he must be encouraged to substitute these motions by rotatory motion in the shoulder, or by extension and flexion of the wrist and elbow. In this latter event, extension of the wrist is accompanied by supination, and flexion by pronation.

Another important substitutionary motion in spastic cases is that of closure of the hand and its release. Extension of the fingers may be accomplished by hyperflexion of the wrist, and flexion of the fingers by hyperextension in a manner similar to that which occurs in some cases of flaccid paralysis. When considering, in those cases, whether or not to perform the arthrodesis of the wrist, it is well to keep in mind the question of substitutionary motion. We have in several cases refrained from arthrodesis of the wrist because the flexion motion of the

LEGEND FOR PLATE XXXIII

Fig. 1.—H. O. Spastic Hemiplegia Trick Motion; Pronation by Flexion of Elbow.

Fig. 2.—H. O. Trick Motion; Supination by Extension of Elbow.

Fig. 3.—A. H. Spastic Hemiplegia; Trick Motion; Pronation by Flexion of Elbow

Fig. 4.—A. H. Trick Motion; Supination by Extension of Elbow.

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wrist was essential to the patient in order that he might release his fingers.

On the other hand, pronation contracture of the forearm was usually an indication for correction, since it was found that even if active pronation was impossible following the resection of the pronator muscles, such motion could be substituted by rotary motion in the shoulder joint (Plates XXX, 3, 4; XXXIII).

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CHAPTER VII

TUBERCULOSIS OF THE UPPER EXTREMITY

Garre's statistics on tuberculosis of the upper extremity, including 145 cases, show the following distribution:

	Per cent
Shoulder 25, or	17.2
Elbow 19, or	51
Wrist 41, or	28.2

Shoulder.—Tuberculosis of the shoulder is rare. Only 2½ per cent of all tuberculous joints involve the shoulder, according to statistics of the Vanderbilt clinic; and, according to the figures of the Boston Children's Hospital, the percentage is only 0.25 per cent. The disease is more common in adolescence than in early life. According to Garre's statistics 42 per cent are found in the first decade and 47 per cent in the second.

In the great majority of adult cases, the disease apparently occurs in the primary synovial form. The synovial surface is studded with tubercles and the entire membrane is thickened and infiltrated. In some cases there is formation of a fungus mass. In others there is a seropurulent exudate. Rarely is there a hydrops articuli with fibrinous precipitates.[1]

In the primary osseous form the seat of the focus is either in the head or in the glenoid fossa. The single caseous foci fuse together and form cuneiform infarcts.

The most frequent form of osseous tuberculosis of the shoulder, however, is the caries sicca or dry tuberculosis. In this disease, thin and avascular granulations are formed, which finally lift off and melt down the cartilage covering and ulcerate the head. It does not produce suppuration.

The onset of shoulder tuberculosis is gradual and insidious. In Garre's series 68 per cent came on spontaneously, while trauma was mentioned in the history in 32 per cent of the cases. Stiffening of the joints is the principal and most prominent symptom, even excelling that

[1] It is quite possible that the older view in regard to the so-called primary synovial tuberculosis in adults will have to be modified. E. H. Nichols, in a careful pathological study published in 1898 (Transactions Am. Orthop. Assoc., Vol. II), states that the disease begins as a rule in the epiphyses of the long bones. A recent study by N. Allison on the subject (Arch. of Surg., May, 1921) led that author to the confirmation of Nichols' view, that the disease is primarily osseous. His conclusions are based upon the microscopic examinations of fifty cases.

of pain. The symptom of gradually increasing stiffening is especially noticeable in the caries sicca in which there is a gradual destruction of the head of the humerus with the breaking down of the tissues. Finally, all motion of the joint becomes lost. The position of the ankylosed shoulder is that of slight abduction, although it is masked, when the arm falls to the side of the body by a rotation of the scapula. The deltoid atrophy is very considerable and much more pronounced than in cases of periarticular lesions, such as subdeltoid bursitis. Tenderness is present over the deltoid muscle or can be elicited in the axilla by pressing against the head of the humerus.

In the fungous type the swelling is considerable and the general condition usually more involved than in the benign type of caries sicca. It is in the fungous forms where the breaking down of the granulations finally leads to the large articular abscesses, and later to the formation of sinuses opening at the shoulder or in the axilla.

The frequent complication with pulmonary tuberculosis makes tuberculosis of the shoulder a serious condition. In the fungous and purulent types, the general condition is much more involved than in caries sicca.

The best final outcome of the tuberculous process is the ankylosis, which, if in favorable position, assures a useful joint. One may hope for this event in the dry form of tuberculosis of the shoulder; in the fungous type, the prognosis becomes much more unfavorable with the breaking down of tissue and the formation of abscesses and sinuses.

Among 5 cases of tuberculosis of the shoulder observed by the writer, 3 were cases of dry tuberculosis and 2 were of the fungous type. The ages varied from 16 to 51 years. The onset of the caries sicca cases was insidious, the symptoms being ushered in by pain and ache at irregular intervals and then stiffening of the shoulder followed. In one case the influence of trauma in the development of tuberculosis of the shoulder was quite evident: a man 51 years old was injured by fall at the age of 7; at the age of 17 and during later life, several forcible stretchings were followed by regular periods of pain. The last stretching, 5 or 6 weeks prior to examination, caused a similar attack. The pain was described as nocturnal, starting at 4 P.M. and interrupting sleep. In this case there was extreme atrophy of the deltoid and no motion of the shoulder in any direction. The gradual development of the disease with stiffening and pain was also noticeable in 2 other cases.

Characteristic findings in the X-ray picture of caries sicca are: atrophy of the bone, disappearance of the joint cartilage, and blotching and honeycombing of the head of the humerus. In the fungous form the bone destruction is much more extensive and the atrophy of bone also reaches higher degrees.

Treatment.—In the beginning of the shoulder joint involvement in children, and, to some extent, adults also, immobilization in plaster casts will not only bring about a subsidence of the acute symptoms but will also secure a better position of the joint. This latter can be accom-

plished by serial casts, applied at intervals of a few weeks, incasing the thorax, the humerus, and the forearm.

Since the duration of the disease averages two to three years, even in most favorable cases, with natural tendency to repair, fixation in plaster must necessarily be prolonged over a period of years. Resection of tuberculous foci will be possible only in a limited number of cases where the foci are situated in the head of the humerus. It is feasible only in cases where the tuberculous foci are recognized as extra-articular not having penetrated into the joint. In most of the adult cases, conservative methods are inadequate and one has to resort to operative means of one form or another.

The results of treatment are reported by Garre, in a series of 24 cases of tuberculosis of the shoulder, of which 7 cases were treated conservatively and 17 operatively.

Of the 7 conservatively treated:

1 was cured.
4 improved.
2 not improved.

Of the 17 treated operatively, in 5 cases the foci were resected:

3 were improved.
2 not improved.

In 12 cases, resection of the head of the humerus was performed:

8 were cured.
3 improved.
1 not improved.

The figures show that of the operative methods the resection of the head gives the better permanent results.

Technic of Resection of the Humeral Head.—Two routes may be chosen; the anterior and the posterior.

In the anterior route, the incision is carried from the tip of the coracoid process down to the interspace between the pectoralis major and the deltoid. On opening the capsule, the tendon of the long head of the biceps is isolated. It is found surrounded by granulation tissue. The capsule is freely opened to the tip of the glenoid cavity, and downward to the tuberosities of the humerus. Then the muscles attached to the tuberosities are elevated until head and neck have been sufficiently cleared to allow of resection of the head.

For the excision of an isolated focus, Harold Stiles gives the following advice: "When a limited focus of the disease is present the curetting followed by the introduction of iodoform or bismuth paste will generally suffice." In more diffuse foci of the humerus, Stiles recom-

mends resection, that is, cutting the bone off immediately below the focus. In doing this, one must take care not to injure the circumflex vessels and, more particularly, the circumflex nerve.

The anterior route was used by the writer in one case. A man of fifty years had a very extensive tuberculosis of the right shoulder of the fungous type, with a large abscess and formation of several sinuses. Resection by the anterior route was undertaken in order to control drainage. The head was resected at the surgical neck. In spite of temporary improvement, the patient continued to decline, finally dying under the symptoms of general septic infection. The autopsy in this case showed a very large abscess at the intersection of the upper and middle lobes of the right lung, which communicated with the great abscess of the shoulder. In this case the resection of the humerus was carried out too late and might have saved the patient had it been performed in time.

The other route used for the excision of the shoulder joint is the posterior method of Kocher. The incision runs from the tip of the acromion process downward and backward to the spine of the scapula and is then carried down in a curved direction toward the posterior fold of the axilla. The acromio-clavicular joint is now opened. The fibers of the trapezius attached to the spine of the scapula are divided and the posterior edge of the deltoid is exposed. The posterior fibers of this muscle are then drawn forward and outward and the supraspinatus and infraspinatus muscles are dissected from the outer border of the spine and the root of the acromion, so that the latter can now be divided with the chisel, carrying with it the attached fibers of the deltoid muscle. This flap is now deflected downwards over the head of the humerus, and a full exposure of the joint capsule effected. The latter is opened, care being taken not to injure the biceps tendon. The insertions of the external rotators are then stripped and held backward while the biceps tendon is retracted forward and outward. The head of the humerus may now be removed, and, when this is done, one obtains an excellent view of the glenoid cavity, and if it shelters any tuberculous foci, they may be properly dealt with. The acromion process is finally wired to the scapula or, if it has not been divided, the periosteum with the posterior fibers of the deltoid are carefully sutured into place. Drainage is installed for a few days.

A point should be made of advocating the early resection of the tuberculous joint in fungous tuberculosis of adults, especially in suppurative types. The anterior incision is the one most favored by Senn, who, in his typical resections, removed the head at the surgical or anatomical neck.

The postoperative treatment consists in the application of a plaster cast in which the shoulder is left quietly until the wounds have definitely healed, or for a period of from four to six weeks. One may then start active motion and, later, very careful passive motion for the purpose of developing the atrophic deltoid muscle.

Tuberculosis of the Elbow.—The elbow joint is more frequently attacked by tuberculosis than the other large joints of the upper extremity. The statistics of the Hospital for Ruptured and Crippled (Whitman) give an incidence of 3 per cent of all tuberculous joints.

The development of this disease occurs mainly in two types. The synovial type is more frequent in adults and leads to early spread of the disease throughout the entire synovial membrane, and to secondary involvement of the bone.

The osseous type is more common in children, and, of the points of the elbow joint, the one most frequently attacked is the olecranon. Next to it is the external condyle of the humerus. The head of the radius is rarely involved. The osseous foci found in the olecranon often have the wedge shape of a necrotic infarct.

Koenig's statistics covered 62 cases, of which 10 were of the primary synovial, and 42 of the osseous type. Of the 42 osseous cases, 22 showed a focus in the olecranon, 17 in the humerus, and only 1 in the radius. In 137 cases reported by Middledorpff, 30 were of primary synovial and 107 of the osseous type.

One of the earliest symptoms of tuberculosis of the elbow is the limitation of motion. It is especially noticeable in the range of flexion and extension, while pronation and supination may be preserved. This is explained by the fact that the radius is rarely, if ever, involved. In several cases under the writer's observation there was complete ankylosis in the humero-ulnar joint while the function in the radiohumeral joint remained unimpaired.

Swelling as a rule appears first to the side and posterior to the condyles of the humerus. With the development of the fungoid masses in the interior of the joint, the latter becomes extended and a generalized swelling follows which gives the entire elbow a round or cylindrical aspect. Perforation of the joint is most likely to take place in the bicipital grooves on the inner and outer side of the biceps muscle or behind the condyles of the humerus, between them and the tendon of the triceps muscle. The swelling is of a peculiar elastic character, due to the thickening of the periarticular structures and the synovial membrane. There is considerable discoloration of the skin just before the appearance of the sinuses. The marked atrophy of the muscles which accompanies fungoid disease of the elbow adds to the appearance of swelling of the joint.

The pathognomonic position of the elbow is midway between extension and rectangular flexion, with the forearm pronated. In cases in which the disease is located in the head of the radius, early swelling appears over this area on the outer side of the elbow joint and in this instance pronation and supination of the forearm become involved very early.

Some observers believe that the general outlook of the disease is unfavorable and that the best to be hoped for is ankylosis in a useful position. For tuberculosis of the elbow in the adult this is probably

true. In children the outlook is by no means as serious as it is in adults and the possibilities for repair with function are much greater than in adults.

Treatment.—It is especially in children that the fixation treatment brings about the best results. The plaster casts applied reach from the axilla to the wrist or palm. The casts are put on in the best position which can be obtained without strain to the joint and pain to the patients. The position most to be desired for the elbow in case of ankylosis is, according to Jones, that of flexion at about 70°, with the forearm midway between pronation and supination.

The writer's series comprises 8 cases of tuberculosis of the elbow among 400 cases of chronic tuberculosis of all joints, equaling 2 per cent.

Case Reports.—C. P., 3 years. Tuberculosis of the left elbow. The disease started 10 months ago with stiffening of the elbow. On examination, the joint was found in a position of 150° extension with very little motion in either direction or in pronation and supination. The X-ray showed tuberculous erosions of the ulna and a tuberculous periostitis in which periosteal bone appeared, laid down in layers separated by granulation tissue. Without application of any force or strain, the patient was treated with plaster casts. After 2 years X-ray showed that the defect in the bone had apparently become filled out. There was now almost normal range of motion. Only extreme flexion and extreme extension was checked and the patient was practically cured.

W. K., 8 years. Tuberculosis of the right elbow. Trouble started 2 years ago with swelling and stiffening of the elbow. When seen, the elbow was fixed in 120° and there was complete loss of flexion-extension movement, although slight supination was possible. No formation of sinuses. The treatment was again that of successive plaster casts which were changed at intervals of 1 to 2 months. After 2 years' treatment, condition was as follows: range of flexion and extension was from 80° to 140°, making the entire range of motion 60°. The X-ray showed the tubercular process apparently healed.

These cases are cited in order to illustrate the possibilities of conservative treatment in juvenile patients and children.

Next to the fixation treatment by plaster cast, heliotherapy is the method to which elbow and the wrist joint tuberculoses are admirably adapted. Rollier, Witmer, and others have reported very favorably on results of heliotherapy in elbow tuberuclosis. Splints should be used in conjunction with it. Of the modifying injections used, the one of 10 per cent iodoform glycerine seems to be most reliable in elbow tuberculosis as well as in tuberculous joints in general. The value of Bier's hyperemia in this affliction is doubtful, although Bier himself gives the percentage of cured as 72.7 per cent and the average duration of the treatment as nine months.

In adults the prognosis is much more serious and, when infection in the joint has become generalized, radical operative interference is unavoidable.

Methods of Resection of the Elbow.—Kocher's incision starts above the external condyle, goes downward, back of the external supracondyloid ridge, to the posterior border of the ulna, about two inches below the tip of the olecranon. From there the incision swings across the olecranon and then inward and upward along the inner border of the triceps so that it assumes a J-shape. Complete access to the elbow joint can now be obtained by sawing through the tip of the olecranon and turning it upward, together with the adherent triceps muscle. In full flexion of the elbow, the lower end of the humerus, the ulna, and the head of the radius come into view. These bones are now protruded out of the wound and resected at any suitable place.

Langenbeck's Posterior Incision.—This incision runs along the middle of the posterior aspect of the elbow joint and is similar to that of Liston, except that the latter's incision is more to the ulnar side of the posterior surface. A most important point in approaching the elbow joint is the avoidance of the ulnar nerve. It can easily be dissected and retracted out of harm's way after it has been lifted out of its groove behind the inner epicondyle of the humerus. After temporary resection of the olecranon, the latter must be fastened back to its base by catgut suture or wire, especially since it is necessary after operation to keep the elbow joint fixed in flexion in the plaster cast.[2] Extension on the forearm may also be used following operation. It affords the advantage of active and passive motion in flexion and extension, a point which might considerably favor function of the joint until it can be left to be supported in a sling. On the other hand, the plaster fixation of the elbow in flexion position reduces the possibility of a flail-joint. Both advantages may be combined by the use of splints after resection, and active motion may begin early; passive motion of the flexion-extension range should wait for some weeks; that of pronation and supination range may be taken up much earlier.

The results in elbow tuberculosis as given in 79 cases by Leonhard are as follows:

Of 17 conservative cases:

- 2 were cured.
- 14 improved.
- 1 not improved.

Of 19 cases treated by excochleation (focus resection):

- 5 were cured.
- 7 improved.
- 7 not improved.

[2] Osgood (personal communication) is convinced that the long straight incision through the triceps muscle and tendon with subperiosteal dissection of the whole elbow joint is the best method of avoiding a flail elbow after resection, and a method which he also advocates for arthroplasty of the elbow joint.

Of 38 cases treated by resection:

28 were cured.
4 improved.
6 not improved.

The late results were as follows: of 12 conservative cases:

3 were cured.
5 improved.
1 not improved.
3 died.

Of 8 cases treated by removal of foci:

2 were cured.
2 not improved.
4 died.

Of 31 cases resected:

22 were cured.
3 not improved.
6 died.

The late observations were made from 9 to 14 years after operation.

These statistics show excellent results following resection. There was never a flail-joint following the resection, although a number of cases had little motion and a number had ankylosis.

In adults the operation of choice seems to be resection of the elbow, while in children the conservative treatment occupies the first place.

Of the writer's 8 cases, 2 were cured by plaster cast treatment (children); 2 adults treated by cast, result doubtful; 1 adult, resected, improved; 1 adult, amputated; and 2 cases were not treated or treatment was interrupted.

Tuberculosis of the Wrist.—The wrist is a comparatively rare location for surgical tuberculosis (8 cases among 400 of surgical tuberculosis, 2 per cent). Among 40 cases reported by Leonhard, 28 had a spontaneous onset, while 12 followed trauma. The seat of the focus in the wrist joint is, according to this author, distributed as follows:

	Cases
Radiocarpal articulation	8
Radio-ulnar articulation	6
Carpometacarpal articulation	8
Carpal bones	12
Lower epiphysis of radius	3
Lower epiphysis of ulna	1
Tendon sheath as primary focus	2
	40

As a rule, the disease is not limited to one bone but quickly involves synovial membranes and ligamentous structures also, and the small carpal bones soon succumb to necrosis and caseation. Suppuration is very frequent, and, if sinuses develop, they are usually situated over the dorsum of the wrist.

The numerous tendon sheaths surrounding the wrist joint often bear direct relation to the process in the joint, inasmuch as tuberculous involvement of the tendon sheaths is a frequent complication, though primary tendosynovial tuberculosis is rather rare.

Mundel calls attention to the prominence of the os magnum as a factor in the development of tuberculosis of the wrist. In three of his cases he was able to show that the disease started from this bone. This he explains is due to the fact that the os magnum is the pivot of the carpal bones which, articulating with seven others, receives the brunt of traumatism directed to the wrist joint. Besides, tension of the ligaments of the carpus causes strain upon the os magnum and he considers the early ossification of this bone, as compared with the other carpals, as an indication of the greater amount of strain imposed upon it.

The position of the wrist in tuberculosis is that of semiflexion of about 120°. Swelling is first noticed at the lateral aspect of the joint, but it soon gains the dorsum and later also appears on the volar surface.

Pain is usually moderate unless there is secondary infection. Barwell states that, in tuberculosis of the wrist joint, the point of special tenderness is on the outer side of the extensor indicis tendon, corresponding to the junction of the os magnum and trapezium.

The muscular atrophy, as in all instances of joint tuberculosis, is very considerable and occurs early.

Tuberculosis of the wrist is essentially a disease of adult and later life and is usually associated with pulmonary disease. It may occur as serous effusion, as caries sicca, or in fungoid form. The latter may show all degrees to general fungoid infiltration and formation of large abscesses. Primary tuberculosis occurs also in the radius as progressive infiltration, or as epiphyseal focus and, finally, also as primary osseous tuberculosis of the bases of the metacarpals with secondary extension into the carpus.

Treatment.—The rarer cases of wrist tuberculosis in children and the synovial and serous forms in general are the object of conservative treatment. In regard to the treatment by plaster cast fixation and modifying injections, as well as by heliotherapy, reference is made to the textbooks on the treatment of joint tuberculosis.

The majority of the cases, especially those with destructive changes in the bone, call for operative measures. But a prompt cure of the local disease can be expected, even from an early operative interference, only when the disease is yet limited in extent.

In accordance with the principle that to cure a tuberculous joint one must destroy it, Ely advocates early arthrodesis, using the following technic: a dorsal, longitudinal incision is made 8 to 10 cm. long, from

the middle of the third metacarpal to 4 cm. proximally to the articular surface of the radius. The extensor tendons are retracted and the periosteum is stripped back. Then, with the motor saw, parallel cuts are made through the wrist joint, radius, and third metacarpal. A graft removed from the tibia is then inserted and fitted into the groove so that it locks when the wrist is forced in hyperextension. The graft is sutured in place, the skin is closed, and a cast is applied which remains for three weeks.

Of the older methods of resection those of Lister, Langenbeck, Ollier, and Kocher are the more commonly known. Lister recommended bilateral longitudinal incisions; one from the styloid process of the radius down to the first metacarpal, and another from the styloid process of the ulna to the fifth metacarpal. From these incisions he resected the carpus by subperiosteal procedure. The incision of Langenbeck is a dorsoradial one, about 9 cm. long, beginning at the middle of the second metacarpal bone over the dorsum of the epiphysis of the radius. The resection is done with the wrist in flexion, removing first the proximal, then the distal row of the carpal bones. Ollier used Langenbeck's method to which was added an ulnar incision similar to that of Lister. Kocher, finally, used a dorso-ulnar incision, avoiding the extensor carpi radialis and the extensors of the thumb. This approach is more difficult than the dorsoradial incision.

Some surgeons advocate early passive motion in order to retain some mobility of the wrist. Such a course is not to be recommended, as it is contrary to the principles governing the management of joint tuberculosis. On the contrary, the period of fixation should be prolonged, and ankylosis of the joint in suitable position encouraged instead of being combated. We know that a fixation of the wrist joint in the position of choice is no serious obstacle to the functional use of the hand and fingers.

It is of interest to study Leonhard's table of results in 40 cases of tuberculosis of the wrist, and to compare his early findings with those made after years of observation.

Early results.

Of 13 cases treated conservatively:

3 cured.
7 improved.
3 not improved.

Of 14 cases for removal of foci:

10 cured.
3 improved.
1 not improved.

Of 2 extirpations of tendon sheath:

2 cured.

Of 5 partial resections (both carpal rows):

3 improved.
2 not improved.

Of 1 arthrectomy:

1 improved.

Of 5 amputations:

5 cured.

Late results.

Of 28 cases treated:

11 died.
6 cured.
6 improved.
5 not improved.

According to these figures, the early and especially the late results are discouraging. Among the joints of the upper extremity, tuberculosis of the wrist gives the poorest prognosis for cure as well as for life.

Of the 8 cases in the writer's series, 6 were improved by conservative treatment. A patient, treated by resection, died later of pulmonary tuberculosis; one patient was amputated.

Tuberculous Dactylitis (Spina ventosa).—The disease is characterized by tuberculous destruction of the diaphysis of the phalanges or metacarpals, which are partly extruded in the form of sequestra. A shell of bone is formed by the periosteum, but this is often so frail that it cannot withstand the pull of the muscles, and, in consequence of it, collapses. This is especially true in cases in which there is early formation of sinuses and a larger amount of bone destruction. The surrounding soft tissues soon become involved and with them also the skin.

The disease has been known for many years and was identified as tuberculosis by Renken in 1886. Malgaigne and Velpeau already had enucleated the basal phalanges in cases of dactylitis and Velpeau recommended primary union of the wound by approximating the fleshy parts.

The radical treatment of tuberculous dactylitis consists in thorough, as well as early, removal of all diseased tissue, especially of every bit of bone involved. In some cases the periosteal shell is strong enough so that it may be left with the expectation of further regeneration. In other cases, however, provisions must be made to substitute bone by autoplasty.

Schmieden used autoplastic methods in 13 cases of operations for spina ventosa, making use of tibial grafts. His incision is a lateral one, saving the tendon, and all diseased soft tissue is carefully removed with the knife. Then the diseased bone is resected. In fistulous cases, he waits for the healing of the sinuses and performs the autoplasty at a secondary operation.

An osteoplastic method is that of Bardenheuer. In order to bridge the defect created by the resection of diseased bone, the basal phalanx is split and one-half of it is used as a bridge.

Albee recommends as the most satisfactory treatment the resection of the affected bone with substitution of the destroyed part by bone graft: an incision is made on the dorsum of the hand in line with the diseased bone. The extensor tendons are retracted. The periosteum is incised and elevated together with the attached interossei muscles. The affected bone is divided with a small single motor saw, osteotome or bone cutter, beyond either end of the diseased bone area, but an attempt should be made to save the head of the bone and not to encroach on the epiphyseal cartilage or to enter the joint. In the phalanges, lateral incisions are employed between the extensor tendons and the digital vessels and nerves. The periosteum is elevated, the bone resected, and an attempt made to save the head and not to destroy the epiphyseal cartilage. The bone defect is replaced by a graft taken from the crest of the tibia. A snugly fitting plaster cast is applied to finger and hand, remaining in place from eight to ten weeks.

F. Smoler (1910) reports on 26 cases operated by the method of Bardenheuer or its modifications. In 9 of his cases the disease was located in the metacarpals and in 10 in the basal phalanges. Of his 26 cases, permanent results were obtained in 30 per cent.

Tuberculous Tenosynovitis of the Hand.—Tuberculous synovitis occurs in the following types:

1. As serous effusion.
2. With the formation of rice bodies.
3. As fungous disease.

The first two forms may persist for months without causing any serious trouble, while the third form is characterized by early involvement of the joint. This type progresses steadily, leading finally to the formation of cold abscesses and sinuses.

The tuberculous tenosynovitis does not show any tendency to spontaneous retrogression. Rather, it goes on without interruption to produce complications, and especially to involve the neighboring structures in the tuberculous process.

Of the three types, the first, or serous effusion type, will yield to puncture and injection of modifying fluids (iodoform-glycerin).

Removal of the rice bodies and excochleation or scraping of the tendon sheath is necessary in the second type.

The fungous form requires radical resection of the tuberculous tendon sheath.

Case Report.—Man, 36 years old, complained for 8 years of a swelling on the volar aspect of the left hand and forearm. He had no pain, nor any serious trouble in the use of the hand, except that gripping was slightly handicapped and the hand tired more easily. The general condition of the patient was excellent.

The examination showed a soft, fluctuating swelling extending from the lower fourth of the volar surface of the forearm through the wrist into the palm. It was less noticeable under the carpal ligament and at the angle between the thenar and hypothenar eminences. But in the palm it became quite prominent more distally, along the sheath of the flexor tendons of the middle finger. There seemed to be a communication between the proximal and the distal portion of the swelling. There was no tenderness to pressure. At operation 2 incisions were made, 1 over the proximal and 1 over the distal portion of the swelling. After dissecting down to the swelling, it was identified as the distended tendon sheath, and incision of it caused the escape of a clear fluid. This was followed by the appearance of rice bodies, which could be squeezed out in considerable numbers. The same procedure was followed from the upper incision and a number of rice bodies were obtained here also. There was a communication between the two halves of the sheaths and the bodies could be forced from one part into the other. The tendon sheaths were carefully scraped and cleaned out and the wounds were closed.[3]

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[3] When seen six months later, there was still a slight amount of swelling, though considerably less than before operation.

CHAPTER VIII

CHRONIC ARTHRITIC DEFORMITIES OF THE UPPER EXTREMITY

Arthritic conditions of nonspecific character, resulting in deformities of the upper extremity, are based upon etiological factors of such variance and diversity that, for the sake of clearness, a short classification of the subject should precede the discussion of this type of deformities. One of the most serviceable is that of L. F. Barker. It is based, not only upon the external appearance of the cases and the course of the disease, but also upon anatomical and etiological considerations, as much as the latter can be correlated with clinical experience. But it neither confines itself altogether to gross anatomical findings, which are at present too general to admit of a detailed division, nor does it base itself upon etiology alone, since here, too, our present knowledge is by far too incomplete to permit an adequate classification.

- Arthritis urica.
- Arthropathies of nervous origin, tabes, syringomyelia.
- Osteo-arthritic deformities.
- Secondary chronic arthropathies following infection.
  - Luetic.
  - Tuberculous (see Chapter VII)
  - Gonorrheal.
  - Chronic articular rheumatism.
  - Chronic progressive polyarthritis.

For the upper extremity there are to be considered the chronic arthropathies following infection, especially the chronic progressive, infectious polyarthritis, and also some of the osteo-arthritic deformities:

Altogether 46 cases of chronic arthritic deformities of the upper extremity have come under the writer's observation.

They are etiologically divided as follows:

Cause unestablished:

	Cases
Shoulder	4
Elbow	3
Wrist and fingers	15
	22

Sepsis following abscess formation:	
Elbow	1
Wrist and fingers	1
	2
Gonorrheal arthritis:	
Wrist and fingers	2
Elbow	2
	4
Septic metastatic infections:	
Elbow	3
Shoulder	1
Wrist and finger influenza	2
	6
Tonsillar and teeth infection:	
Wrist and fingers	4
Elbow	5
Shoulder	1
	10
Sinus infections:	
Wrist and fingers	2
	46

Regarding the etiological significance of teeth and tonsillar infection in chronic arthritis, while it is not within the scope of this writing to enter into this question systematically, yet, in the light of the material at hand, brief reference must be made to this matter. It is over a hundred years since Benjamin Rush first called attention to the possible connection between diseased tonsils and chronic arthritis. The teachings of Billings and the investigations of Rosenow have in later years stimulated the interest in this problem. Although the early enthusiasm, which followed Rosenow's discovery of the transmutability of streptococcus strains, has given way at the present time to a degree of skepticism, the interest in this question is still alive and it is to be hoped that it will not be allowed to wane. The opinions are at present widely divergent; some hold to the belief in an underlying focal infection in any case of chronic arthritis, while others deny the significance of this factor. Most orthopedic surgeons hold that the removal of a focus in teeth or tonsils, or in the accessory nasal cavities, will produce a cure in some, and improvement in a number of cases, and more so in acute than in chronic conditions. Hammond's statistics of 40 cases show that there were diseased teeth or tonsils in 29. But in all his cases there was only one in which immediate and striking improvement

followed so closely the removal of the focus of infection that a causal connection between focus and arthritis could not be denied. In the writer's series there were 7 cases in which a connection between foci in teeth, tonsils, sinuses, or ear was established in the history and in which removal of these foci gave no relief. There were, furthermore, 10 cases in which careful search for a focus was made and in which removal of tonsils, clearing of sinuses, etc., did not produce improvement nor did it check the progress of the arthritis. But there were, on the other hand, 9 per cent, or 4 cases, of chronic arthritis of the upper extremity, in which decided improvement was obtained after removal of tonsils or clearing of sinuses.

Case Reports.—P. R., 8 years, suffering for 3 years from infectious arthritis involving feet and hands. Examination showed sinusitis and empyema of right antrum. Operation on sinuses and antrum was followed by distinct improvement which continued during an observation of 2½ years.

F. B., 13 years, suffering for years from chronic infectious arthritis involving fingers, shoulder, elbows, knees, and ankles. A suppurative anterior ethmoiditis was found and treated. This was followed by gradual improvement and final arrest of the progress of the disease.

M. O., 5 years, suffering for 3 years of chronic infectious arthritis of all joints. Chronic tonsillitis. Tonsils removed. Antromeatal operation. This was followed by marked improvement of the arthritic condition.

A. P. J. Infectious arthritis of the right elbow for a number of years, with considerable pain. Removal of tonsils 6 years ago was followed by disappearance of pain within 1 month.

The use of foreign proteins injected intravenously (typhoid vaccine) has been recommended in later years (J. Miller, H. B. Thomas). As an initial dose in several cases, 25 to 50 million bacteria to 1 c.c. was used. Only in two instances was there anything like an improvement. In 1 case with involvement of right hand, wrist and elbow showed a remarkable improvement after 7 injections from 50 to 125 mm. which, after 4 months of observation, still continued. In the other case, 6 injections up to 75 mm. were used with moderate improvement.[1]

Arthritic Deformities of the Shoulder.—The increasing limitation of motion in the shoulder soon leads to complete immobilization followed by atrophy of the deltoid. The trouble may be recognized as an intra-articular lesion and differentiated from extra-articular conditions by the position of the shoulder joint, which is, as a rule, that of 25° abduction.

[1] Lately the work of R. Pemberton on the etiology and treatment of chronic arthritis has attracted the widest attention. In his numerous publications he emphasizes the metabolic nature of this condition. Pointing to the beneficial influence of X-ray, of radium, of endocrine therapy, which factors also stimulate metabolism, he thinks it evident that there is a definite relation between the food intake and arthritis. This, together with observations of low sugar tolerance, and of the favorable influence of starvation and especially low carbohydrate diet, lead to the theory that the arthritis is caused by lowered respiratory and metabolic capacity of the organism, induced not only by focal infections, but also by exposure, chronic intestinal condition, etc. He consequently recommends a generally reduced diet with special restriction of the carbohydrates.

This position is masked by rotation of the shoulder-blade but can easily be detected by restoring the symmetrical position of the scapula (compare Chapter I). There is usually a degree of tenderness of the joint capsule, most apparent in the axilla where the inferior portion of the capsule can be reached. Arthritis of the shoulder joint is to be differentiated from the following conditions:

Stiff and Painful Shoulder Following Sprains.—It is usually the anterior and inferior portion of the capsule which is involved, the injury being acquired in abduction and outward rotation of the arm. The position in this case is that of adduction and inward rotation contracture. The capsule is tender in the pit of the axilla and evidences of infiltration may be found there.

Sprain and Tears.—Adduction and internal rotation contracture are caused by sprains or tears of the pectoralis major and latissimus dorsi tendons. The tender points are precisely localized at the sites of insertions of the tendons.

Subdeltoid Bursitis.—Limitation of motion is partial as in the other two conditions, outward rotation and abduction being inhibited. Local tenderness is found over the subdeltoid bursa or over the anterior portion of this muscle.

Caries Sicca.—In caries sicca, the onset is gradual, accompanied by little pain, and stiffness is an early symptom. The contracture is that of an intra-articular lesion, that is, in slight abduction. Signs of pulmonary tuberculosis are often present. The affliction is usually monarticular.

Treatment.—The treatment of the chronic arthritic shoulder deformities is essentially one of rest and immobilization. In the subacute stages the contracture yields more readily to the application of a platform splint. By gradually raising the angle the adduction contracture can be overcome. Massage, passive and active motion are valuable aids in the treatment. Forcible manipulations in arthritic conditions are not to be recommended. They are usually followed by an exacerbation of the inflammatory condition. Even at best, they contribute nothing to the mobility of the joint and they may do considerable harm. From this point of view alone, it is important to differentiate between intra-articular and extra-articular lesions, as in the latter forcible manipulations to overcome contracture may be employed.

Case Reports.—J. N., 14 years. Septic arthritis of the left shoulder following mastoid operation 1 year ago. Fixation of the shoulder in slight abduction and inward rotation. Atrophy of the deltoid. Treated conservatively with splints and massage. Condition after 14 months: has active abduction of 70° in the shoulder joint. Almost complete rotatory and flexion and extension movement in the shoulder. Considerable regeneration of the deltoid.

S. S., 46 years. Chronic arthritis of the shoulder developing for 1 year. Complained of pain and stiffness. There was rigidity of the right shoulder with muscular contraction, the position of the joint being 30° abduction.

Treated by splints, and massage. After 4 months the right arm can be abducted to the perpendicular.

Arthritic Deformities of the Elbow.—The position of the elbow in rheumatoid or infectious arthritis is that of extension to 130° to 150° and of pronation of the forearm. It is the object of early treatment to avoid the danger of ankylosis in this unfavorable position.

Fixation of the elbow is best procured by a plaster cast reaching from the metacarpophalangeal joints to the axilla, or by a splint of similar extent. In earlier stages, and especially in certain types of infections, the position can be improved by a series of casts until a position of 70° to 80° flexion and midway between pronation and supination is obtained. Corrective casts should include the lower radio-ulnar articulation.

It has been common experience that the forcible breaking up of adhesions in the elbow joint is followed by a flare-up of the inflammatory condition with subsequent increase of the intra-articular adhesions. Gonorrheal adhesions in the elbow joint are among the least likely to cause such violent reaction to force, and, for the sake of improving the position, the application of moderate force may be justified at times. But under no circumstances should an increase of the range of motion be expected to follow the forcible mobilization of the elbow joint. This procedure is invariably followed by a severe hemorrhage into the joint and often by extra-articular hemorrhage also, which leads to an increased production of fibrous adhesions.

Cases of ankylosis of the elbow from chronic arthritis: 15.

Causes:	*Cases*
Ear and throat infections	5
Erysipelas	1
General septic infection	3
Acute articular rheumatism	1
Gonorrheal infection	2
Cause unestablished	3
	15
Degree of ankylosis:	
Total	2
Partial	13
	15
Treated conservatively:	
Improved	3
Not improved	2
	5

Forcible correction:

Improved	1
Not improved	1
	2

Arthroplasty:

Improved	3
Not treated	5

Arthritic Deformities of Hands and Fingers.—The position of hand and fingers in arthritic contractures is one of flexion in the wrist joint, of ulnar deviation of the fingers with either flexion or hyperextension in the metacarpophalangeal joints, and of flexion in the phalangeal joints.

The principles of fixation and gradual correction of the contractures should be applied to the wrist and fingers with the same persistence as in other joints of the body. Appropriate splinting especially will go far to check the increasing contractures of the flexor muscles. The best services will be obtained from the volar appliances with individual volar finger splints in which the degree of correction can be regulated according to the condition of the individual joint. A dorsal ring splint may be applied also, but we have found that pressure upon the first interphalangeal joint is not well tolerated.

In some cases the volar flexion of the wrist is extreme; these also show a tendency to hyperextension in the metacarpophalangeal joints. This deformity reaches, in some cases, a degree where a veritable condition of subluxation exists between the radius and the carpus; occasionally the lower end of the radius follows the direction of the contracture with a volar incurvation and the ulna, not following the radius, becomes prominent at the dorsum of the wrist; a condition simulating the picture of Madelung's deformity.

A chronic, ankylosing arthritis of the wrist joint is often observed following injuries of the wrist, that is, Colles' fractures or even mere contusions and sprains. It is marked by spastic contracture of all the forearm muscles and the muscles of fingers and wrist. The process leads finally to obliteration of all joints of the carpus. It occurs more often in nervous individuals and in persons of more advanced age, and is probably based upon reflex nervous and circulatory disturbances.

Treatment—The Deformity of the Wrist.—Splinting and massage in cases of lesser rigidity, in cases with tenderness or occasional recrudescence of more acute symptoms. Corrective manipulation in more resistant cases. The cast should reach from the palm to the elbow and be applied at intervals varying from a few days to a few weeks. Occasionally a forcible correction of the deformity may be undertaken under anesthesia. This, however, should be restricted to resistant contracture in the chronic stage, not showing acute acerbations, and in which the carpus shows no tendency to subluxation. In exceptional cases the

LEGEND FOR PLATE XXXIV

FIG. 1.—I. B. INFECTIOUS ARTHRITIS, WRIST AND FINGERS.

FIG. 2.—F. B. ANKYLOSIS, ELBOW AND WRIST; INFECTIOUS ARTHRITIS.

FIG. 3.—A. P. INFECTIOUS ARTHRITIS. CAST FOR CORRECTION OF FINGER DEFORMITIES.

FIG. 4.—F. S. TRAUMATIC ARTHRITIS; BONE EROSIONS. ADDUCTION CONTRACTURE.

FIG. 5.—F. S. FOLLOWING OPERATIVE TREATMENT (ARTHROLYSIS AND TENOTOMIES).

FIG. 6.—F. B. INFECTIOUS ARTHRITIS; FINGERS, ELBOW, WRIST AND SHOULDER.

FIG. 7.—J. N. SUBLUXATION OF WRIST; IN INFECTIOUS ARTHRITIS.

FIG. 8.—A. P. FINGER CONTRACTURES; INFECTIOUS ARTHRITIS.

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2

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4

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correction may also be facilitated by plastic lengthening of the contracted flexor tendons of the wrist.

Mueller (1894) reported 3 cases of arthritis deformans of the wrist joint treated with extirpation of the capsule, trimming of the articular surfaces, and resection of the scaphoid and lunare. For arthrotomy of the wrist one may employ with advantage Ollier's posterior incision: from a point midway between the styloid processes, an incision is made on the dorsal surface and carried down through the posterior annular ligament to the middle of the second metacarpal, radially to the extensor indicis tendon.

The Deformities of the Metacarpophalangeal Joints and Fingers.—The hyperextension of the metacarpophalangeal joint is best managed by splinting combined with massage and passive motions in cases which are not too resistant. In the latter type, correction could be obtained by manipulation with or without anesthesia, the result of correction being secured by a plaster cast which holds the fingers closed. Considerable difficulty is encountered in meeting the extension deformities of the fingers. One may gradually force the phalangeal joints into flexion by corrective splints, or may do so by manipulation in one sitting. The former procedure, if feasible, is preferable because the friable capsular tissues and the degenerated tendinous structures react severely to the application of force.

TABLE OF CASES.—Total deformities of hands and fingers		25
Causes:		
Tonsillar and sinus infections	6	
Influenza	2	
Gonorrhea	2	
Cause not established	15	
	25	
Deformities:		
Flexion contracture of wrist alone	8	
Flexion contracture of wrist and fingers	9	
Flexion contracture of fingers alone	2	
Extension of fingers and metacarpophalangeal joints	2	
Subluxation of the wrist	1	
Ankylosis of wrist, no deformity	3	
	25	

Treatment:		
Splints and massage		10
Improved	7	
Not improved	3	
	10	
Cast		3
Improved	2	
Not improved	1	
	3	
Forcible correction		3
Improved	3	—
Total treated		16

(Plate XXXIV, 1-8).

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CHAPTER IX

CONGENITAL MALFORMATIONS AND DEFORMITIES

The study of congenital malformations and deformities of hand and fingers leads into the darkest period of the embryological and ontological development of man. In the first period of intra-uterine life, covering the first two months, the agencies which are capable of producing malformation seem to be most powerful. The activities of growth and development are so intense, at this time, that any disturbance of these must have grave morphological consequences.

A number of theories have been brought forth in an effort to shed light upon the factors responsible for congenital deformities. Some of these views are necessarily speculative and cannot very well be substantiated, especially as they reach back into the very early life of the embryo. Other theories consider mechanical factors and external forces: position, outside pressure, etc. The latter have in their favor greater plausibility in general, but when it comes to their application to the individual case, the field for mechanical theories becomes greatly limited.

The former type is represented by the archipterygial or primitive ray theory of Gegenbaur. It is, according to him, the suppression of development of any of the primitive rays which is responsible for the occurrence of certain deformities. If the first primitive ray of the upper extremity is involved, the bones affected are the radius, scaphoid, trapezium, the first metacarpal, and the thumb. This is a theory which is applicable to a limited number of congenital deformities only. On the other hand, a representative of those which point to external forces in explaining the origin of deformities is the amniotic theory of Schwalbe, Dareste, and others. Here it is amniotic pressure or mechanical constrictions from amniotic bands which are held responsible for such deformities as hemimelia, phocomelia, etc.

In the course of the discussion of the different types and groups of congenital deformities of the upper extremity, it will become clear that it is a futile attempt to subjugate all the different deformities of so heterogenous a type and character, or even a great majority of them, to any one of the theories which have been advanced. So, for instance, the amniotic theory, very applicable to cases of external amniotic constriction, furrows, and certain cases of syndactylia, fails in the explanation of a great many other deformities. Those theories which rely upon primary aberrations and variations have a wider applicability, especially in deformities of a bilateral and symmetrical character. There should also be mentioned the views which ascribe to certain malforma-

tions of the spinal cord and spinal column an essential rôle in the production of congenital deformities, such as claw-hand, congenital claw-foot, etc. Finally, it must not be overlooked that polyglandular disturbances, especially functional anomalies of the hypophysis, may be responsible for some of the congenital malformations of more general type.

While as a whole the theory of embryonal aberration or primary aberration covers the greater part of the cases of congenital malformations of the hand and fingers, it seems certain that other factors also come into play and that no one theory is capable of covering even the large majority of cases of congenital malformations.

Classifications.—The most thorough and scientific classification of the congenital deformities we have found to be that of Potel, which we quote here, adapted to the conditions of the upper extremity.

Congenital Deformities in Regard to Upper Extremity

Classification of Potel:

- I. Embryonal evolutionary type
  - A. Osteogenetic disturbances
    - 1. Systemic osseous dystrophy
      - a. Enchondral ossification (achondroplasia, hyperchondroplasia, hereditary dystrophy arachnodactylia)
      - b. Periosteal dysplasia (osteopsathyrosis)
      - c. Disturbance of ossification of membranous bone (congenital absence of clavicle)
    - 2. Localized osseous dystrophy
      - a. Ectromelia (brachymelia, micromelia)
        - aa. Transverse
          - (1) Hemimelia
            - absence forearm and hand—E. vera
            - absence of hand alone—ectrochiria
            - absence of fingers—ectrodactylia
            - brachydactylia—microdactylia
          - (2) Phocomelia
            - absence of segments
            - humerus, forearm bones
        - bb. Longitudinal E.
          - absence of radius, partial or total
          - congenital club-hand
          - absence of ulna
      - b. Skeletal hypertrophy
        - gigantism, partial or total
        - macrodactylia
      - c. Deficient segmentation and fusion
        - elbow, forearm bones
        - carpal bones
        - syndactylia: osseous fibrous, membranous
        - acrodactylia

d. Hypersegmentation
  aa. Transverse (polydactylia)
  bb. Longitudinal (hyperphalangism)
e. Axial deviations (comptodactylia, clinodactylia)
f. Heteroplastic aberrations {osseous developmental aberrations osteogenetic exostoses

B. Articular Malformations
1. Relaxations (hyperextension elbow, wrist; congenital clownism)
2. Subluxations (shoulder, thumb)
3. Congenital dislocations (shoulder, elbow, radius, thumb)

C. Muscular Malformations
1. General muscular dystrophies (congenital contractures)
2. Localized
  a. Congenital elevation of the scapula
  b. Congenital atrophy of deltoid
  c. Congenital contracted club-hand

II. Amniotic type
A. Cicatricial
1. Amniotic amputations
2. Amniotic strands
3. Amniotic furrows

B. Compression
1. Amniotic syndactylia

A clinical classification less complex and applicable to most of the conditions of the upper extremity, but at variance in many respects with Potel's classification, is the following:

Clinical Classification

A. Deformities by developmental suppression, agenesis
1. Congenital defect of the forearm bones (congenital club-hand)
2. The cleft hand (lobster claw-hand)
3. Ectrodactylia (aphalangism)

B. By developmental arrest
1. Syndactylia
2. Symphalangism

C. By developmental aberrations
1. Polydactylia (some cases)
2. Hyperphalangism

D. Dysplastic conditions
1. Congenital synostoses
2. Brachydactylia (some cases)
3. Fusion of carpal bones

E. Polyglandular dystrophy
   1. Polydactylia (some cases)
   2. Macrodactylia (partial gigantism)
   3. Arachnodactylia
F. Contractures (neurogenetic or amniotic)
   1. Contracted club-hand
   2. Contracted fingers
   3. Amniotic contractures (nonsymmetrical)

Much of the difficulty in properly classifying a case is due to its complications. For instance, it is not unusual to find polydactylia, ectrodactylia and syndactylia together in one case. In fact, there seems to be a certain relationship between overdevelopment and suppression. It is to be hoped that further investigations both of embryological and anatomical nature will bring more light on the questions of etiology.

Embryology.—The embryology of the upper extremity can be found in W. H. Lewis' excellent article, "American Journal of Anatomy" (1901), which is here quoted in part:

The first indication of the arm bud appears during the 3rd week as a slight swelling of the lower cervical region on the anterior portion of the Wolffian ridge. This gradually enlarges, and, by the time the embryo is 4.5 mm. in length and 3 weeks old, the arm is of considerable size. The base now lies opposite the lower 4th cervical and the 1st thoracic vertebrae. The arm bud is at first filled with a homogenous mesenchyme. No nerves or myotomes have yet entered the arm. During the 4th week, before the nerves enter, differentiation begins by increased condensation of the skeletal core. During the 5th week, the nerves from the first anlage of the cervicobrachial plexus push into the premuscle sheath which surrounds the skeletal core.

By the end of the 5th week, the skeletal core can be differentiated into many of the skeletal elements, three of which contain cartilage, namely, humerus, ulna, and radius. The premuscle sheath also becomes more or less differentiated into several groups of muscles, but at first without sharp lines. Toward the distal end differentiation is less complete and, in the hand, premuscle tissue still represents the intrinsic muscles. The nerves have grown into the hand by this time and most of the branches of the brachial plexus found in the adult are now present.

By the end of the 6th week, most of the muscles of the arm can easily be recognized. The intrinsic muscles of the hand are just beginning to show fibrillation. The tendons and ligaments are also becoming more sharply differentiated. Most of the skeletal elements consist of cartilage and the surrounding perichondrium. The distal row of phalanges are not yet differentiated. The nerves, both sensory and motor, are distributed much as in the adult.

During the end of the 7th week, all skeletal elements are of cartilage except the distal row of phalanges, from the second to the fifth

digits, which are of condensed tissue. All muscles are differentiated and muscle fibers are present. Tendons and ligaments, except in the distal parts of the digits, are well formed.

One will note from these embryological facts that the development of the skeletal plant (anlage) occurs, practically entirely, between the third and seventh week. Another point of importance is that the development of the nerve system is ahead of the differentiation of the muscle system, a point with which the neurogenetic theory of malformation has to reckon.

During the development of the upper extremity, there occurs a certain migration of the arm which changes its topographical relation to the spine. The whole extremity migrates caudally. The scapula, for instance, which in the embryo of four weeks occupies a place opposite the fourth and fifth cervical vertebrae wanders downward, so that in the sixth week the greater portion of the scapula lies below the first rib and the lower angle reaches the fifth rib. This fact has already been mentioned in discussion of the congenital elevation of the scapula, a condition which really belongs in this chapter, but has, for reasons of expediency, been placed by the writer among the shoulder affections of the upper extremity.

The brachial plexus also has a very marked caudal inclination indicating the migration of the extremity. There is also a migration of the pectoralis muscles and the latissimus dorsi from a more anterior to a posterior plane of the thoracic wall, and, by the seventh week, the pectoralis muscles have reached the adult position. The trapezius muscle also wanders caudally. In the embryo of four and one-half weeks, the posterior end of the trapezius premuscle mass lies no further down than the fourth cervical. At the end of six weeks, it already reaches the fifth thoracic vertebra. Such migration also occurs in the serratus magnus muscle, which wanders downward from the cervical region, and in the rhomboids, which migrate, between the fourth and seventh weeks, from the level of the fifth cervical to a definite position in the thoracic region. This embryological migration is a factor in several congenital deformities about the shoulder and arm; not only in congenital elevation but also in certain anatomical variations of the thoracic muscles.

A-1. Congenital Club-hand.—Suppression of the development of the first ray, which includes radius, scaphoid, trapezium, the first metacarpal, and the thumb, is, according to Gegenbaur, responsible for the majority of cases of club-hand deformity. Developmentally, the radius is behind the ulna and it can therefore be understood why suppression setting in at a certain moment will find the ulna developed and the radius partially or totally undeveloped. The suppression of growth, however, is not confined to the radius alone nor to the first ray in general. There are cases in which the defect involves the ulna and the ulnar ray. The radial defects are, however, by far in the preponderance over the ulnar defects in the group of club-hands associated with bone involvement.

Up to 1904, Kirmisson reported 67 cases, 57 of which showed total and 10 partial bone defect. Antonelli (1912) reported 114 cases with total or partial defect of the radius and Whitmann in 1912 could collect more than 200 cases in the literature.

The majority of all cases of this type are associated with defects of the radius. Among the congenital defects of the ulna, of which there is a small minority, a family of 9 is mentioned by Blencke in which 4 members showed the deformity. Bilateral club-hands are about as frequent as unilateral. Complications with deformities and defects of other nature are very common, and among those complications there are mentioned club-foot, congenital deformities of the thorax, fusion of the ribs, and many others.

Anatomical details concerning these deformities have been described by Kirmisson and Longet. Kirmisson dissected a case of total defect of the radius with absence of thumb. He found all the thumb muscles, as well as the muscles of the radial side of the forearm, entirely absent; and in addition to this, the long head of the biceps was also missing. The defect involved radius, scaphoid, semilunar, trapezium, as well as the skeleton of the thumb. The superficial and the deep flexors are often found united in one mass at the upper end of the forearm, and it is with difficulty only that they can be differentiated by their distal insertions. There is no flexor of the thumb nor index finger, if the latter is missing too, and there is no pronator quadratus. In the case described by Kirmisson both supinators were absent. There was one small muscle blending with the muscles of the posterior region of the forearm which probably represented all that was left of the extensors carpi radiales. Of the posterior group, the anconeus and the extensor of the fifth finger were missing. In the hand, small bundles from the pisiform bone represented the abductor of the fifth finger, and there were only three ulnar lumbricales. No muscles at the radial border of the hand or of the thenar were present.

In cases of ulnar club-hand, the defect involves not only the ulna but also one or two of the metacarpals and phalanges. Cases are reported in which the ulna was entirely missing and only two radial digits existed. In the case reported by Neumann, for instance, the third, fourth and fifth fingers were absent and there was total defect of the ulna.

The anatomical data are more meager in regard to the ulnar club-hand than they are in regard to the radial. Watts found a bilateral congenital absence of the ulna in a monodactylous fetus, an additional finger being attached at the elbow, where a web was binding the forearm to the humerus. In this case, the superficial extensors of the forearm were present and the deeper group was missing. The forearm flexors were represented but were badly disorganized and disarranged. In the remainder of the hand, there was only one muscle, a lumbricalis, arising from the lateral side of the tendon of what was considered to be the flexor pollicis muscle. Dislocation of the head of the radius was found in connection with a defect of the lower end of the ulna in a case of

ulnar club-hand reported by Kirmisson. In this case, three fingers were
and a third finger.
fully developed: the thumb, a completely fused index and middle finger,

A second group of cases of congenital club-hand deformity are those which are not associated with bone defects. As to the etiology of this deformity, we are entirely in the dark. It is certain that the amniotic theory cannot easily be called upon in explanation of this deformity if the bilaterality and symmetry of it is considered. Potel groups these cases under muscular malformation of localized character. They are truly contracted club-hands and by some considered as club-hands in the stricter sense of the word because of their analogy to the ordinary congenital club-foot.

According to the type of contracture, one may distinguish ulnar, palmar, radiopalmar, ulnardorsal, and radiodorsal club-hands.

The author's series embraces 12 cases of congenital club-hand:

	Cases
A. Defects of forearm bones	
Congenital defects of the radius	3
Congenital defects of the ulna	2
B. Contracted club-hand	7

Club-Hand

congenital club-hand

Case	Age	Deformity	Bone Defects; Complications	Treatment	Result
P. S.	3 mos.	bilateral symmetrical congenital club-hands	congenital defects of radius	splint treatment; operative treatment deferred	
K. Mc.	5 mos.	congenital bilateral club-hand bilateral symmetrical	total defect of right radius both thumbs missing	operation osteotomy of ulna	fair
M. W.	8 wks.	congenital club-hand, right	partial defect of radius: only lower epiphysis and part of upper developed	deferred operative treatment	
H. P.	14 mos.	ulnar club-hand	total defect of ulna; syndactylia between 2d and 3d finger	osteotomy of radius	poor, recurrence
C. K.	17 yrs.	bilateral ulnar club-hand	symmetrical rudimentary ulnar; lower 3d missing; only 7 carpal bones; function of hand good	not treated	

CONTRACTED CLUB-HAND: BILATERAL, SYMMETRICAL

Case	Age	Deformity	Bone Defects; Complications	Treatment	Result
C. M.	11 mos.	contracted club-hands bilateral	contraction elbows; adductor contraction of the arms; flexion contracture hips and knees; congenital club-foot; genital hypoplasia; high palate	not treated	
F. T.	7 yrs.	flexion contracture of the left hand	Atrophy of shoulder muscles; contracture of elbows; fragilitas ossium; callus of the humerus	plastic lengthening of fingers; arthrodesis of wrist	good; both deformity and function
G. H.	8 yrs.	congenital contracted club-hands bilateral symmetrical, ulnar deviation	congenital flexion contracture of hips and knees; contractures of shoulders; bilateral congenital flat-foot; high palate; genital hypoplasia; function good	not treated	
A. B.	10 yrs.	congenital contracted club-hands; ulnar deviation; bilateral; symmetrical	congenital contractures of the knees. congenital club-foot; cutaneous syndactylia between thumb and index fingers	operative correction of syndactylia muscle education	Good
F. C.	6 mos.	congenital bilateral symmetrical club-hands with ulnar deviation	genua recurvatam bilateral; total absence of the patellæ; function good	club-hands not treated	
E. T.	6 mos.	congenital bilateral club-hands ulnar abduction	adduction contractures of the shoulders; congenital club-feet; webbing of the bases of the fingers (*pterodactylism*)	splints and plastic lengthening	fair
D. A.	$1\frac{1}{2}$ yrs.	rachitic contracted club-hands since birth	rachitic deformities of legs and hands; function good	not treated	

(Plates XXXV, XXXVI, XXXVII.)

LEGEND FOR PLATE XXXV

Fig. 1.—D. C. Bilateral, Congenital, Radial Club-hands. Defect of Radius.

Fig. 2.—K. McC. Bilateral, Congenital, Radial Club-hands; Absence of Radii; Thumbs Missing (X-Ray).

Fig. 3.—K. McC. Bilateral, Congenital, Radial Club-hands.

Fig. 4.—F. C. Contracted Club-hands.

Fig. 5.—H. P. Congenital, Ulnar Club-hand, Left. Absence of Ulna.

Fig. 6.—E. T. Contracted Club-hand, Syndactyl, Left.

Fig. 7.—E. T. X-ray of Contracted Club-hand.

Fig. 8.—A. B. Contracted Club-hands.


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LEGEND FOR PLATE XXXVI

Fig. 1.—A. D. Rachitic Contracted Club-hands.

Fig. 2.—G. S. Congenital Contracted Club-hands.

Figs. 3, 4.—X-rays of Contracted Club-hand.

Fig. 5.—G. H. Congenital Contracted Club-hands.

Fig. 6.—J. D. Rachitic Contracted Club-hands.

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LEGEND FOR PLATE XXXVII

Fig. 1.—L. M. Acquired Club-hand (Osteomyelitis).

Fig. 2.—L. S. Acquired Club-hand (Osteomyelitis).

Fig. 3.—R. G. Neoplasty of Thumb. Italian Flap Method.

Fig. 4.—R. G. End Result.

Figs. 5, 6.—R. G. X-rays.


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Treatment.—In the treatment of club-hand deformity without bone defects, that is, in cases of contracted club-hands, tenotomies or tenoplasties are usually found sufficient. These measures must be followed by prolonged fixation in corrected position. More advanced cases, with bowing of radius and ulna, need osteotomy or excision of a wedge-shaped piece of bone from the curve in the forearm. The maintenance of the corrected position is quite a problem and success will follow only persistent and painstaking after treatment. Splints must be worn for a long time and the muscle power of the extensors must be carefully developed by manipulation, massage, and passive motion.

The treatment of the skeletal club-hand deformity usually involves operative interferences on the forearm bone. Bardenheuer split the ulna longitudinally and implanted the carpus between the two halves. McCurdy severed the ulna at a point near the proximal edge of the carpus and then implanted the proximal end of the ulna into the carpus. Vulpius used periosteum flaps from the ulna after he had corrected the deformity. Albee implants a tibial graft obliquely into the carpus at the distal end and into the ulna at the proximal end.

In the writer's series of 12 cases, 3 were operated upon: 1 by osteotomy of the ulna, and 2 by osteotomy of the radius. The immediate results were good, but 2 of the cases later showed the recurrence of the deformity. In some of the cases not operated upon, the treatment applied was that of massage, splinting, and muscle educational exercises.

The reason for the conservatism which was observed in the treatment in general was the astonishingly good function of hand and fingers seen, especially in cases of contracted club-hands; besides, complicating deformities, such as club-feet, which called for early treatment, made it necessary to postpone for some time the treatment of the hands; this was the case in two patients of this series. How far one may go in correcting this deformity by splints is rather hard to determine. Mild and moderate degrees of contracted club-hands will yield to the use of corrective splints. In more advanced cases, operative procedures on the forearm bone must be carried out. The muscle contractures, and the shortening of the soft structures, vessels, nerves, etc., may put an early limit to splint correction and impose the necessity of operative correction of the forearm, in a limited number of cases. However, early stretching or tenotomies followed by painstaking splint treatment will make most of the cases of contracted club-hands amenable to correction without operations on the bone; this leaves, then, essentially the skeletal group of congenital club-hands for the osteoplastic methods.

A-2. The Cleft Hand (Lobster claw-hand).—This is a very rare deformity, of which only a few cases so far have been reported in the literature. A. H. Tubby reports a case of cleft hand extending through five generations and associated with cleft feet. Cases of bilateral lobster claw-hand deformity associated with cleft foot have also been reported by McKnight and Brandenburg. Of 4 cases reported by Bircher, 2 showed hereditary tendencies (mother and daughter). Combinations of

this condition with polydactylia, brachydactylia, hyperdactylia, spina bifida, and other deformities have been described.

Case Reports.—R. B., 9 days. No family history was obtainable. The right hand showed a fully developed thumb and index finger on the radial side and a fully developed little finger on the ulnar side. Between these 2 fingers, there was a deep cleft reaching to the carpus. The left hand showed radially a thumb and index finger, both being united by a syndactylous web. On the ulnar side there was a fully developed little finger and between the latter and the index finger there was a deep cleft reaching to the carpus.

The thenar muscles on both sides seemed to be fully developed and excellent motion of the fingers was observed, except for the lack of opposition of the thumb. The feet showed a similar cleft. On the right foot, there was a cleft between the 1st and 4th toes, the 2nd and 3rd toes being missing, the cleft reaching to the tarsus. On the left there was a cleft between the 1st and 5th toe, the 2nd, 3rd and 4th toes being missing, the cleft also reaching to the tarsus. A plastic operation for the improvement of the syndactylia on the right hand was performed. Aside from this, no radical operation was attempted to correct the cleft, as it was noticed that the patient was using his hand with increasing skill and that the forceps motion of the cleft hands was very useful. The patient was finally able to hold on to objects and developed a considerable amount of dexterity in the use of his hands, especially the adductor movement of the finger. However, there was no opposition movement of the fingers in the sense of the opposition of the thumb (Plate XXXVIII, 1).

B. H., 8 months. Right lobster claw-hand. There is a deep cleft reaching to the carpus between what appears to be the thumb and the index finger. The latter, however, is abnormally large. There is a fully developed little finger. The others are missing. The X-ray picture shows that the large index finger is clearly a fused 3rd and 4th finger, all phalanges being completely united. The 3rd and 4th metacarpals are normally developed. The 5th finger is normal. The 2d finger is totally missing, together with its metacarpal. The case is complicated by congenital absence of the tibiae and congenital absence of the patellae. In this case, also, no attempt was made to correct the claw-hand deformity, as the function of the hand promised to be good (Plate XXXVIII, 5, 6).

A-3. Ectrodactylia.—Ectrodactylia is the congenital absence of one or more of the entire fingers including the metacarpals. The cleft hand which was described in the foregoing paragraph is a type of ectrodactylia. In unilateral cases, amniotic amputations may be considered as the cause of this deformity, but other cases must necessarily have their explanation of their origin in theories of primary aberrations which interfere with the development of the hand. Tubby distinguishes a marginal and central group. In the marginal group, the fingers of the radial or ulnar border are suppressed (oligodactylia). In the

LEGEND FOR PLATE XXXVIII

Fig. 1.—R. B. Congenital, Bilateral, Lobster Claw-hand.

Fig. 2.—Ectromelia and Ectrodactylia.

Fig. 3.—R. E. Ectromelia and Ectrodactylia.

Fig. 4.—R. E. X-ray.

Fig. 5.—M. H. Right, Lobster Claw-hand.

Fig. 6.—M. H. X-ray, Showing Fused Third and Fourth Finger (Giant Finger).

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central group, the defect of the fingers and metatarsals results in the cleft formation already described. Klippel and Rabaud, who report 4 cases of total ectrodactylia, make a distinction between an *ectrodactylie phalangienne,* where the fingers are represented by small stumps carrying osseous nodules which articulate with the metacarpals, and an *ectrodactylie metacarpophalangienne* in which the metacarpals are missing, as well as the fingers. In the case reported by Lewin, the 3rd and 4th fingers were missing, and in Judet's case there was a total defect of all fingers, three carpals alone being present. This latter case already presents a form of ectromelia or defect of all fingers. It is interesting to note that combinations have been described by Atwood of ectrodactylia with polydactylia combining a deformity by suppression with one by hyperformation. Luaces also reports a combination of ectrodactylia with syndactylia. Often, however, it is difficult in alayzing the deformity to decide whether one deals with a proximal fusion of two fingers or a distal bifurcation of one.

Case Report.—R. E., 3 years. Ectrodactylia of both hands. There are present on the left hand the thumb and 1 finger; on the right, 2 central fingers are present, both thumb and little finger being missing. The 2 fingers on the right hand are syndactylic. There is total absence of the ulna and complete fusion between humerus and radius on the left extremity; and, on the right side, there is complete absence of the radius, with fusion of the ulna and humerus at right angle (Plate XXXVIII, 2, 3, 4).

Aphalangism.—Aphalangism is the absence of single phalanges of the fingers. It may be considered as a mitigated type of ectrodactylia. The deformity has a pronounced hereditary tendency. Cragg and Drinkwater have reported a family of 5 generations, in which there were 25 abnormal and 17 normal members. The deformities were divided between brachydactylia (short fingers) and entire absence of phalanges. The absence concerns the terminal phalanges alone and farther reaching defects seem to be unknown, the types going on to complete ectrodactylism or total absence of fingers. It seems that in this group the theory of amniotic amputation finds its application, except that the bilaterality of the condition offers some difficulty of explanation.

Case Report.—F. E., 10 years. Congenital lack of end phalanx of the index fingers. The deformity is bilateral and symmetrical, and was complicated by cleft palate and congenital club-foot.

B-1. Syndactylia.—Dareste, an adherent of the amniotic theory, in his study of the anomalies and congenital deformities of the limbs, ascribes to amniotic influences certain forms of syndactylia as well as other deformities such as ectromelia and hemimelia. Central neurogenetic influences and primary developmental variations or reversions to earlier type have likewise been mentioned in the etiology of syndactylia. The differences in the types of syndactylia, however, are such

that it does not seem possible that a single theory could cover the many clinical variations. Tubby divides syndactylia as follows:

Finger web or cutaneous syndactylia.

Skin and fibrous connective tissue webs.

Bony fusion.

Kirmisson speaks of the first type as *syndactylie membraneuse.* In cases apparently completely fused, in giant fingers, for instance, the bony fusion is not always as complete as the morphological fusion. Cases are reported of apparently totally fused giant fingers bearing but one nail in which the X-ray shows complete skeletal separation of two fingers (Nove-Josserand).

Partial fusion of the fingers and metacarpals is not uncommon. In some cases the fusion involves only the proximal half of the phalanx, giving the distal part the appearance of bifurcation such as seen in polydactylia. It is at times difficult to decide whether one has to deal with a polydactylous finger attached to the distal half of the end phalanx or with a proximal fusion of the finger. In some cases one observes a type of fusion which involves the distal parts of the fingers mainly, causing them to be matted together closely, whereas the bases are found to be comparatively free (acrosyndactylia). Identification of the individual fingers in these cases is often quite difficult.

Combinations with other deformities are quite frequent. Syndactylia is often associated with cleft hand, club-hand, or polydactylia. We have observed syndactylia in two cases of ectrodactylia and ectromelia. In contracted club-hands, cutaneous syndactylia is especially frequent. Other deformities such as acrocephalia, cleft palate, etc., at times complicate the deformity (Ruh, Davis, Bertolotti). The anatomical observations of Klippel and Rabaud have furnished some data in regard to the circulatory conditions in syndactylic fingers. These authors have found in their cases that the superficial palmar arch descends as far distally as to reach the proximal phalanges. The bifurcation from this arch of collateral arteries was therefore much more peripheral than in the normal hand.

Anomalies of the insertion and the course of the tendons have also been studied and reported. The findings naturally vary extensively almost with each individual case.

Syndactylia is a deformity which shows a strong hereditary tendency and reports on syndactylic families are quite frequent in the literature. Luaces mentions a syndactylic family of 39 with 14 syndactylous members, the deformity in some instances skipping one generation.

Treatment.—A number of operative methods have been devised for the treatment of syndactylia in different forms and stages. The method of Zeller consists of the longitudinal splitting of the web with a triangular flap left to cover the base. Tubby tunnels the finger at the base and lines the tunnel by flaps raised from both sides of the finger. Later, after the canal has been established and properly lined, he deals with the distal end of the web. The most generally adopted method of

treating simple syndactylia is that of Didot, which consists of a sort of trap-door incision made both on volar and dorsal sides, by which flaps are raised having their bases laterally on opposite sides. When these flaps are liberated and the fingers pulled apart, the free skin can then be turned around the adjacent sides of the fingers, making the covering complete. The flaps are then sutured to the skin at the middle of the volar side on one finger and at the middle of the dorsal side on the other. This method avoids the placing of skin sutures at the opposing lateral surfaces of the fingers, a precaution which prevents the recurrence of the fusion. Spitzy treated some of the cutaneous cases by small prisms which were pressed against the web, thinning the latter out by gradual compression. This thinned-out web is later divided by clipping.

No single method is applicable for all cases nor even for a majority of cases of syndactylia. The greatest difficulty is to obtain a sufficient amount of skin; especially the adjacent sides of the finger should be thoroughly covered to prevent a reappearance of fusion. It seems that, even with the plastic methods of Didot, one hardly ever obtains enough skin for covering in cases where fusion is more complete.

In some cases the author has used to good advantage abdominal flaps which were so placed that they could be fastened in the interdigital space of the separated fingers and were large enough to furnish ample material of skin.

The writer has had under observation 12 cases of syndactylia, 8 of which were operated on.

In the after treatment following operations for syndactylia, the postoperative dressing is a matter of greatest consequence. It is not infrequent that a graft showing a considerable amount of vitality becomes later devitalized in its edges by profuse secretion and maceration of skin. The writer has been in the habit of dressing cases on which skin plasty had been performed as early as two or three days after operation, taking good care that a proper spread of the fingers is always secured. When the wounds have healed definitely, constant attention must be paid to the scars, owing to the fact that they have a great tendency to contract. Wherever possible, a scar is placed on the dorsal surface, but when a volar scar is unavoidable, the finger is held in complete extension for a period of several months, with a dorsal finger splint applied. In the mechanical after treatment, active motion of the fingers is of the greatest usefulness. Not only should flexion and extension movement be practiced, but abduction and adduction motion of the fingers should also be encouraged and when systematic drills and muscle educational exercises are planned and devised, this point should be kept in mind. This is especially true in cases of webs between the thumb and index fingers in which there is a great tendency for adduction and flexion of the thumb. By muscle exercises, especially by rotatory motion of the thumb carried out several times a day in regular sittings, together with a painstaking splint treatment, such postoper-

Table of Cases of Syndactylia

Name	Age	Deformity and Complications	Treatment	Results	Remarks
C. L.	7 yrs.	syndactylia 3rd and 4th fingers left; cutaneous syndactylia between 4th and 5th fingers	plasty method, Didot	good	similar deformity in uncle
M. E.	2 yrs.	webbing of 3rd and 4th fingers of both hands with contracture of middle finger	not treated		mother had webbed fingers on left hand; in maternal grandmother's family two members affected; dedeformity handed down through female members
R. J.	5 mos.	cutaneous web between thumb and index fingers both hands, preventing abduction of thumb	not operated		no heredity
T. L.	16 yrs.	syndactylia fingers left hand; 2nd, 3rd, 4th fingers fused complete from tip to base; right hand, 3rd and 4th from tip to base; 2nd and 3rd from base to end of proximal phalanx (Plate XXXIX, 1, 2)	operation 3rd and 4th right; Didot method; 3rd and 4th; left: abdominal flap	good	one brother with 3 fingers missing
C. A.	4 mos.	complete bony syndactylia; all fingers of both hands (acrosyndactylia)	not operated		no heredity
M. J.	2 yrs.	syndactylia right hand; total fusion 3rd and 4th fingers	operation; plasty, Didot	good	no heredity
J. C.	4 yrs.	syndactylia both hands; webbing of all fingers with partial cleft between thumbs and index fingers	not treated		no heredity; cleft palate; brachydactylia
M. W.	25 yrs.	syndactylia right, complete cutaneous syndactylia 3rd and 4th	plasty of Didot	fair	treatment interrupted
B. S.	3 yrs.	partial syndactylia both hands; symmetrical webs between 2nd, 3rd, 4th and 5th; web between 4th and 5th partial	plasty of Didot	good	symphalangism in mid-phalangeal joint, bilateral symmetrical, 2nd and 3rd fingers; X-ray shows bone fusion in 4th
F. S.	8 yrs.	bilateral acrosyndactylia; fusion of 3rd, 4th and 5th fingers both hands; fusion of nails; bones distinctly separated	operation Didot	good; 4 completely separated fingers	syndactylia both feet; webbing of 3rd and 4th toes
L. D.	12 yrs.	bilateral symmetrical syndactylia; cutaneous webs between 3rd and 4th fingers; bones entirely separated	Didot's operation	good	similar deformity in one cousin
W. F.	7 wks.	bilateral syndactylia; acrosyndactylia right index and 3rd fingers; left—all fingers fused at tips	operation plasty; steps: separating 2nd and 3rd fingers right; isolating thumb and 5th fingers left; separating 2nd and 4th fingers left; resection of rudimentary 3rd finger left	fair, 4 fingers obtained on on left hand	no heredity

(Plates XXXIX, XL.)

LEGEND FOR PLATE XXXIX

Fig. 1.—T. L. Syndactylia.

Fig. 2.—T. L. Final Operative Result.

Fig. 3.—L. T. Syndactylia, Left Hand, Complete.

Fig. 4.—L. T. X-ray. Showing Skeleton Complete Except Basal Phalanx III and All End Phalanges.

Fig. 5.—Baby F. Acrosyndactylia.

Fig. 6.—Mrs. W. Syndactylia.

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LEGEND FOR PLATE XL

Fig. 1.—L. D. Syndactylia before Operation.

Fig. 2.—L. D. Syndactylia after Treatment.

Fig. 3.—C. W. Syndactylia before Operation.

Fig. 4.—C. W. Syndactylia after Operation.

Fig. 5.—M. J. Syndactylia after Operation.

Fig. 6.—C. L. Syndactylia after Operation.

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ative contractures may be avoided. Of the 8 cases operated upon, Didot's method of plasty was used in 6 cases, the flap method was used in 1 case and a simple plasty in another case. In this connection, there should be mentioned a technic of Pieri for the relief of the contracted thumb. This method consists in the formation of two triangular flaps in the web between thumb and index finger, which are obtained by an incision at the edge of the web, and two additional incisions at the opposite extremes on the web at right angle, one going down on the volar and one on the dorsal surface. When these flaps are liberated and the thumb and index fingers are pulled apart, the skin flaps are turned over the corresponding surfaces of the metacarpals of the thumb and index finger. In this way the natural web between the thumb and the index finger is deepened. This method has also been used by the writer on several occasions with satisfactory results (Plate XXI, 1, 2, 3).

B-2. Symphalangism.—Symphalangism is a very unusual and extremely rare condition of the fingers, which essentially consists in a fusion of the interphalangeal joints. This fusion is not always a true bone fusion, but often represents extra-articular contractures only, especially of ligamentous and tendinous nature. In the latter instances, the X-ray picture shows a separation of the phalanges and a joint slit, although the latter is often very narrow and incomplete. True bone fusion is so uncommon that Rimbaud considered his case as absolutely unique. Instances of this kind, however, have been repeatedly mentioned in the literature. The most extensive list is that of Goldflam, who cites 26 cases in 3 generations out of a total of 46 members of the family. The writer has observed 2 cases of symphalangism, both occurring in members of the same family.

Case Reports.—W. S., 3 years. Bilateral cutaneous syndactylia between 2d, 3d, 4th, and 5th fingers. The X-ray pictures show true fusion between the basal and end phalanx of the 4th finger and of the 5th finger on both hands. In the 5th finger, the line between basal and middle phalanx cannot be seen, while in the 4th finger the place of the 1st interphalangeal joint is merely indicated by an indentation. In the 2d and 3d finger, the joint is present but the joint slit is very narrow. Passive motion was possible to a limited extent in the 1st interphalangeal joint of the index fingers and it was barely indicated in that of the middle finger, while the 4th and 5th fingers were entirely stiff. An attempt was made to force flexion and extension movement but, while it was partly successful for the index fingers, it completely failed for the middle finger. The deformity was entirely symmetrical on both hands.

Baby S., 6 months, sister of W. S. The deformity is absolutely identical with that of the brother of the child except that the fusion in the 4th finger is even more complete than in the brother. In the 5th finger, however, there is an indication of a middle phalanx represented by a small round shadow. This case also showed fusion of the radius with

the humerus on the right side, whereas the brother's elbow was normal in this respect (Plate XLI, 1, 2, 3).

C-1. **Polydactylia.**—In polydactylia again, a central and a marginal type may be distinguished. The condition may originate from a bifurcation over the metacarpophalangeal joints, in which case there is a total duplication of fingers; or there may be a bifurcation of the metacarpal bones or of the phalanges themselves. In the latter instance, there is then an approachment to syndactylic forms with complete fusion, a point which has been referred to before. The marginal form, that is, the duplication of the thumb and little fingers, is by far the more frequent type.

Heredity is a distinct feature of this type of congenital deformity. Bernard mentioned an instance of polydactylia covering 5 generations; in the cases reported by Brandeis regarding a hexadactylous family and in the polydactylous family of Atwood, a good illustration is given of the influence of heredity. The largest report on familial deformities of this type is that of Moore who, in a family of 7 generations, found 20 cases of polydactylia among 237 members. Amrein reports 7 sisters with hexadactylia. Many other instances of this kind are on record, too numerous to mention.

Some anatomical data of the condition are at hand. In a description of Danforth it is noted that the supernumerary fingers contained a cartilaginous core not attached to the other bones of the hand. The abductor digiti minimi was sending slips into a supernumerary digit attached to the 5th finger. On the volar side, he found that branches of the proper digital nerve supplied the extra finger. These fingers often present all the elements of a normal finger in a shortened and more or less abortive condition. Polydactylia is often found in combination with other deformities, not only of the hand itself, but also of other parts of the body. Darest described a case of retinitis pigmentosa and coloboma of the iris combined with polydactylia. There are many cases on record of polydactylia associated with polyglandular syndromes such as obesity, genital hypoplasia, etc. Such combinations seem to throw a new light upon the influences of endocrine glands in the formation of deformities.

Case Reports.—J. C., 2 years. Polydactylia of the right hand. Duplication of the end and basal phalanx of the thumb. Of the radial accessory phalanx, the end phalanx had been removed, but the basal phalanx had been left, and patient presented himself on account of deviation of the thumb to the ulnar side. The operation consisted in the removal of the accessory proximal phalanx of the thumb and in the correction of the deviated end phalanx of the thumb proper by osteotomy.

A. J., 1 year. The patient showed a very small rudimentary supernumerary little finger attached to the ulnar border of the hypothenar eminence. This supernumerary finger carried a distinct nail. It was removed and the examination showed that it had no cartilage core but

LEGEND FOR PLATE XLI

Fig. 1.—W. S. Cutaneous Syndactylia and Symphalangism.

Fig. 2.—W. S. X-ray. Fusion of Mid-phalangeal Joints 3, 4 and 5.

Fig. 3.—M. S. Sister of W. S. X-ray. Symphalangism. Fusion of Mid-phalangeal Joints, 3, 4 and 5.

Fig. 4.—Polydactylia. Rudimentary Accessory, Fifth Finger, Bearing Nail.

Fig. 5.—J. C. Polydactylia. Part of Polydactylous Thumb Removed.

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consisted mainly of fibrous tissue; it had a perfectly separated, tiny, individual flexor tendon (Plate XLI, 4, 5).

C-2. Hyperphalangism.—This condition is characterized by the existence of four instead of the three phalanges of the fingers or of three instead of the two phalanges of the thumb. The mode of development of the phalanges throws some light upon this deformity. The phalanges in the embryo are differentiated in serial order, the basal one appearing first and the terminal one last. According to Grafenberg, the terminal phalanges show evidence of two elements, a proximal and a distal one. When the distal one fails to unite with the proximal one, it may cause the appearance of a fourth phalanx. This deformity may be considered as a reversion to type, as the primitive digits are probably composed of many phalanges. Embryologically, it is a developmental arrest consisting in failure of fusion between the two halves of the terminal phalanx. It is an extremely rare deformity. Reynolds described a case in which the thumb had the appearance of the fifth finger with the terminal phalanx so shaped as to make the thumb like one of the digits. Curiously enough, there was no thenar eminence and the hand was flat. In 2 cases of Joachimsthal, the index fingers had four phalanges each, and in a third case reported by him, there was hyperphalangism of the third finger. The X-ray showed distinct deviation from the normal type of ossification. In the case of Joachimsthal, the distal end of the basal phalanx showed an abnormal epiphysis. Pfitzner reported 3 cases of three-jointed thumbs. He considered the middle phalanx as the supernumerary one, as it showed neither a distinct epiphysis nor an articular surface. But a case of epiphysis of the middle phalanx on both hands is reported by Freund; on the other hand, in the instances described by Dubreuil-Chambardel, there was a distinct joint dividing the second metacarpal into two unequal parts so that the supernumerary link seemed to be given off by the metacarpal instead of the phalanx. There is, in the literature on this deformity, a good deal of discrepancy both in regard to the seat of the supernumerary link and in regard to the part the epiphysis plays in the formation of the deformity.

D-1. Congenital Synostoses—*a. Radio-ulnar Synostosis.*—Congenital synostoses of both forearm bones is occasionally observed. The seat of the synostosis is usually the upper end of the forearm bone. The radio-ulnar synostosis constitutes a serious obstacle to the pronation and supination movement of the forearm. The forearm is usually held in extreme pronation and either passive or active supination is entirely impossible.

Case Report.—B. D., 8 years. Congenital radio-ulnar synostosis of the right forearm. The forearm is held in extreme pronation, passive supination being impossible; flexion and extension in the elbow is free. The X-ray shows a synostosis of the proximal radio-ulnar joint and operation is advised but refused.

The treatment of this condition is entirely operative. The most efficient method is the resection of the synostotic head of the radius with or without interposition of the flap of muscle between radius and ulna. In cases in which the synostosis reaches farther down, occupying the entire upper fourth of the forearm bone or more, the operative procedure is fraught with considerable difficulty. The mere resection of the bone bridge and the interposition of muscle flap does not seem to give as good results, according to reports in the literature, as does the complete resection of the syndactylic part of the radius, which causes a new radio-ulnar joint to be formed more distally.

b. Congenital Synostosis of the Humerus with the Forearm Bones.—The writer has observed 2 cases of this type. They were associated with other deformities and have accordingly been mentioned in previous paragraphs.

Case Reports.—W. E., 4 years. Ectrodactylia. This case shows a complete synostosis of the radius with the humerus at the left elbow and a complete synostosis of the ulna with the humerus at the right. The ulna is united with the humerus at almost right angle, whereas the radius is united in extended position. The musculature of the arm and forearm is very much underdeveloped and a differentiation of the flexors and extensors of the elbow or of the pronators and supinators cannot be made.

Baby S., 6 months old. Case of cutaneous syndactylia and symphalangism. This case shows a complete fusion of the radius with the humerus on the right side while the left elbow is entirely free. The fusion between radius and humerus is at an angle of 135° (Plate XLII, 1-6).

E. Polyglandular Dystrophy.—In regard to the polyglandular dystrophy, a short perfunctory mentioning of this condition as an underlying cause of deformity of the hand is sufficient. It is doubtful, to say the least, whether or not the polyglandular condition of the body is the underlying cause or merely a coincident. Cases of polydactylia have been described with marked polyglandular defects.

E-1. Polydactylia.—Polydactylia has been observed in connection with polyglandular dystrophy. The majority of cases of polydactylia, however, do not belong to this group, although, as mentioned before, it is in this deformity especially where hereditary influences are most marked.

E-2. Macrodactylia.—The diagnosis of this condition must be made with caution. True macrodactylia or partial gigantism is extremely rare. Most cases of so-called giant fingers are associated with severe deformities, especially with cleft hand. A close study, supported by the X-ray picture, shows that most of these giant fingers are more or less complete fusions of the skeletal and soft parts of the digits.

E-3. Arachnodactylia.—Arachnodactylia is a very rare condition. It is usually a degenerative stigma, the principal feature of which is the

LEGEND FOR PLATE XLII

Fig. 1.—C. A. Congenital Partial Ankylosis Elbows. Contractures Shoulders and Wrist.

Fig. 2.—C. A. X-ray. Right Elbow. Deformity of Joint.

Fig. 3.—M. S. X-ray. Congenital Fusion of Radius and Humerus, Right.

Fig. 4.—R. E. Fusion of Both Elbows. Ectrodactylia.

Fig. 5.—R. E. X-ray. Left Elbow. Fusion of Radius and Humerus, Absence of Ulna.

Fig. 6.—R. E. X-ray. Right Elbow. Fusion of Ulna and Humerus, Absence of Radius.

PLATE XLII


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LEGEND FOR PLATE XLIII

Fig. 1.—O. W. Congenital Contracture of Thumb.

Fig. 2.—O. W. After Operation.

Fig. 3.—L. T. Amniotic Furrowing of Fingers.

Fig. 4.—L. T. After Operation.

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unusual length of the fingers especially the end phalanges which are tapered at the ends. We have observed only 1 case of this kind in a child with heavy hereditary taint.

F. Congenital Contractures and Amniotic Furrows.—There is a distinct group of congenital deformities of hand and fingers, in which the action of amniotic strands and adhesions is so evident, that there is little room for doubting their importance in the formation of this deformity. Amniotic furrows are often seen encircling the fingers, the thumb, the hand and wrist, and the constriction leaves distinct and deep grooves which sometimes go on to complete amputation of the finger or even hand or forearm.

F-2. A special type of deformities are congenital contractures of the fingers and thumb. The fingers are found drawn into flexion position by cutaneous webs which run from the volar surface of the fingers into the palm of the hand. These contractures seem to be different from what is seen in contracted club-hands; probably here, too, amniotic adhesions are at work in producing this deformity. The writer has observed 3 cases of this type.

F-3. Case Report.—L. T., 2 years. This patient showed amniotic furrows and grooves at the index, 3rd and 4th fingers of the left hand. Motion was in no way restricted and there did not seem to be any damage to the deeper structures. This case was complicated, besides, by a spontaneous amputation of the right leg in the lower third of the tibia and by absence of the end phalanx of the 2nd toe of the left foot. These deformities were also clearly caused by amniotic constriction. The grooves in the fingers were treated by excision and subsequent skin plasties (Plate XLIII, 3, 4).

Case Reports.—J. P. Contracture of the little finger of the right hand since birth. The case resembles clinically that of Dupuytren's contracture except that it is congenital and not progressing. The motion of the finger is intact. The contracture is caused by fascial bands running from the base of the little finger to the palm of the hand.

G. J., 12 years. Both 5th fingers of the patient here held in flexion position by a web extending from the middle phalanx to the bottom of the hand. This case was operated by a skin plasty and the deformity was cured (Plate XLIII, 1, 2).

H. A., 1½ years. There was a congenital contracture of the 2nd, 3rd and 4th fingers of the left hand, together with flexion contractures of the wrist. The deformity was remedied completely in the 3rd and 4th fingers, while the correction of the 2nd finger was only partial. This case also showed a congenital elevation of the scapula and a multiple fusion of the ribs on both sides. There was also wedge formation of the 5th dorsal vertebra. The first two cases may be classified as amniotic contractures. The third case, however, cannot be placed in this group, because af the concurrence of other deformities, that is, the involvement of the spinal column, the existence of an elevated scapula, and the anomalies of the ribs. These complications demonstrate the

more central origin of the deformity. The development of it must necessarily date back into a very early period of embryonal life.

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CHAPTER X

TRAUMATIC DEFORMITIES

Traumatic Deformities of the Hand and Fingers—*Dislocations of the Hand*—Total Radiocarpal Dislocations.—Complete posterior dislocations are accompanied by laceration of the posterior capsule of the lateral ligaments; often, also, by fracture of the styloid process of the ulna. Complete anterior dislocations are accompanied by lacerations of the anterior carpal and lateral carpal ligaments. The hand is held in extension.

Isolated Carpal Dislocations.—Dislocations of the semilunar, os magnum, scaphoid, pisiform. In isolated dislocations of the carpus, those of os magnum have not been reported, but cases are described of isolated dislocation of the head of the bone alone or together with uncinatum. Isolated dislocation of trapezium and trapezoid have not been observed. A fracture sprain of the pisiform bone occurs occasionally, caused by the pull of the flexor carpi ulnaris.

The typical lesion is the dislocation of the os lunatum. It is caused by forcible hyperextension when both the lunare and scaphoid are pressed against the volar surface of the wrist. The dislocation is always volar, the lunare being squeezed out in the forcible hyperextension movement. All observers agree that dislocation occurs during dorsiflexion, often by a violent push against the volar surface of the hand. According to Potel, dorsiflexion of the wrist causes volar dislocation. The mechanical factor is the pressure exerted against the os lunatum by the os magnum distally and the radius proximally; but it is hard to decide whether the pressure from the proximal or from the distal end is the main factor which forces the bone out of its position.

The symptoms of the dislocation are pain, swelling and disturbance of function. It is the dorsiflexion more than abduction and adduction which is restricted. Pronation and supination are usually normal. In this dislocation, the fingers, especially the second, third, and fourth, cannot be closed. If the os lunatum is very prominent in the volar surface, flexion contracture of the finger may occur. Violent pain is caused by forcible movements, especially by gripping and closing the fist. The pain may radiate into the fingers and arm. Even paresis of the median nerve with sensory disturbances, atrophy of the thenar muscles and glossy skin have been observed in cases of dislocation of the semilunar bone.

Chronic Cases.—In chronic cases, the symptoms are not caused by the dislocation alone, but also by the traumatic arthritis which follows the

injury. The arthritis is intimately connected with the displacement, and the removal of the dislocated bone usually gives considerable relief.

The treatment of chronic cases is that of removal of the bone. It can be reached by volar incision, made between the palmaris longus and the flexor carpi ulnaris (Hessert and Lilienfeld). Some authors prefer an incision between the palmaris longus and the flexor carpi radialis (Poulsen). The results of the resections are, on the whole, good. They are better if there is little or no secondary traumatic arthritis complicating the dislocation.

Case Report.—E. M. F., 20 years old. The patient fell a month ago upon the extended hand from a height of 5 feet, injuring his right wrist. The symptoms were swelling, pain, tenderness, and inability to flex the wrist. The X-ray showed a forward dislocation of the os lunatum. An attempt to reduce under ether failed. The patient gained so much under mechanical treatment that the plan of resection of the bone was abandoned.

Isolated dislocation of the scaphoid is hardly ever observed. All old and unreducible dislocations of the carpal bones become orthopedic problems owing to the marked disturbance of function. The only appropriate treatment for these lesions is the removal of the dislocated bone. Most of these cases become irreducible within a few weeks after the injury.

Chronic Traumatic Dislocation of the Phalanges.—According to Webber's statistics covering 198 dislocations in general, 20, or over 10 per cent, were those of the phalanges. The usual dslocation of the phalanges is that of dorsal dislocation of the distal portion. The dislocation in the interphalangeal joint is less frequent than the dislocation in the metacarpophalangeal joint. Reports of Guibé on the metacarpophalangeal and interphalangeal dislocations show 84 in the metacarpophalangeal joints of the thumb, 27 in the metacarpophalangeal joints of the fingers, 26 in the first interphalangeal joints of the fingers, and 69 in the second interphalangeal joints.

Of great orthopedic interest are the dislocations of the thumb. A classification of Faraboeuf distinguishes in metacarpophalangeal dislocations between complete dislocations and incomplete dislocations on one side, and so-called complex dislocations on the other, according to the relation of the sesamoid to the dislocated joint. In the incomplete dislocations, the sesamoid still adheres to the joint surface of the metacarpal. In the complete dislocations, the sesamoids are displaced distally together with the distal portion. In the complex dislocations, they are wedged in between metacarpal and the basal phalanx.

The most frequent form is the interphalangeal posterior dislocation caused by fall upon the extended thumb or by blow. There is a tear in the capsular ligament and often, also, laceration of the lateral ligaments of the thumb. Piquard and Dubar published 2 cases, the one from operation, the other from autopsy, that showed the rupture occurring at the insertion of the capsule to the basal phalanx. The extensor

tendon of the thumb itself almost always remains intact (Malgaigne). Fracture of the base of the distal phalanx is a not infrequent complication.

Guibé distinguishes in these dislocations between a complete and an incomplete displacement. In the incomplete displacement, the distal phalanx rests with its articular surface upon the head of the basal phalanx at a more or less right angle. In the complete displacement, the distal phalanx is pushed entirely over the head of the basal phalanx, so that the axes of these two bones are parallel.

Within a very short time, these dislocations become irreducible. This irreducibility is caused by two factors. One is the displacement of the extensor tendon; the other is the interposition between the articular ends of fibrous and tendinous tissue. It is, in fact, only in the first few days that a reduction of the dislocation by manipulation is possible without great difficulty.

In reducing the dislocation, flexion suffices for the incomplete type. In complete dislocation, however, traction and pull forward is necessary, together with hyperextension. Pailaillon found 13 of his 55 cases irreducible.

In the event that reduction is impossible, open operation is indicated. A flap incision is made over the dorsal side of the articulation, the convexity of the flap pointing distally. Then the extensor tendon is carefully dissected and drawn aside. The resection of the interposed capsular tissue is now possible. It is often necessary to resect the head of the basal phalanx also, and this can be done without fear of a stiff or ankylosed joint.

Forward dislocation of the thumb is much more infrequent than posterior dislocation. It may also be divided into two groups—complete and incomplete. In incomplete dislocation, the distal phalanx rests upon the head of the basal phalanx with its posterior border at more or less right angles. In the complete dislocation, the distal phalanx is dislocated upward as well as forward and the axes of the bones are parallel. Reductions of this dislocation have been reported by Poinsot and Cyrus Pirondi, the latter succeeding in reducing a dislocation on the sixth day; but ordinarily, dislocation here, also, becomes irreducible within a few days and open operation again must be resorted to. The technic is similar to that in posterior dislocation.

Case Reports.—Sister M. B. Subluxation of the thumb. The thumb pulled out of joint 3 years ago while the patient was working. The examination shows the subluxation of the thumb between the 1st metatarsal and the trapezium. The subluxation became reduced automatically in flexion of the finger.

Mrs. C. N. Old dislocation of the finger. Injured finger 4 months ago by fall. Examination reveals a posterior dislocation in the 1st interphalangeal joint of the little finger, entirely irreducible. The patient is treated operatively. Resection of the head of the phalanx is carried out from a posterior flap incision.

N. R., 1 year. Posterior dislocation of the end phalanx of the right thumb. Irreducible. Treatment by operation: opening of the joint, resection of the capsule and reduction.

Dislocations of the Fingers.—These usually occur as the result of a fall or blow upon the fingers forcing the joints into hyperextension and resulting in posterior displacement of the distal portion. Lateral dislocations of the fingers by direct violence, such as a blow, are not infrequent and are usually accompanied by a fracture sprain of the bases of the distal phalanx. A rupture of the lateral ligaments is also present. The reduction of all dislocations of this type very soon becomes impossible and operative interference is necessary.

Fracture Deformities of the Hand and Fingers.

Carpus. Fractures of the individual carpal bones.

Forearm fractures. Typical Colles' fracture of the radius and ulna; fracture of styloid process of the ulna; fracture of styloid process of radius.

Fracture deformities of fingers.

Fracture of Scaphoid.—The most common fracture among the carpal bones is that of the scaphoid. In fracture of the scaphoid, the tenderness is located at the dorsum of the wrist at or about the snuffbox. There is, secondarily, a development of traumatic arthritis in the single joints of the wrist. The mechanism of the injury in fracture of the scaphoid is usually a fall upon the extended hand. Pain and inability to flex the wrist are the most prominent symptoms. All flexion movement of the wrist becomes painful.

The fracture of the scaphoid should be differentiated from the wrist sprain caused by distortion. Most patients with wrist sprain complain of pain at the radial or radiodorsal region. Only exceptionally is the ulnar region involved. The pain is strictly localized to this region. There is tenderness upon pressure, especially in volar flexion of the wrist and in ulnar abduction. This pain is a distention pain due to the fact that the carpal reinforcing ligaments are strained at the radiodorsal or radial surface. Occasionally there is pain on dorsiflexion and on radial abduction which may be explained as a compression pain, but the typical pain in wrist distortion is localized on the radial and radiodorsal side and becomes more evident in flexion of the wrist. The anatomical basis is the injury to the lateral radial ligament and the radiodorsal ligament, although occasionally the lateral ulnar ligament may be involved.

Case Report.—R. A. Old fracture of the scaphoid. Patient fell 8 months ago upon extended hand. Since then he complained of pain and inability to move the wrist. Examination showed tenderness of the wrist below the tip of the radius; passive motion free; active extension painful. The X-ray showed fracture of the scaphoid. In this case, the symptoms of scaphoid fracture were indefinite and there was reason to construe the syndrome as strain of the dorsolateral structures, but the X-ray picture cleared up the diagnosis (Plate XLVI, 6).

The treatment of the fractured scaphoid involves the application of massage, heat, passive motion and splint and plaster immobilization, and there are cases of undoubted fracture of the scaphoid in which function returns to normal, even though the fragments never really unite except by fibrous union.

In the majority of cases, however, operative interference is necessary. The operation consists in partial excision, the proximal fragment being usually the one more easy of access.

Fracture Deformities of the Wrist—*Colles' Fracture.*—The disability following Colles' fracture of the wrist depends, as to degree and duration, upon several factors. The actual deformity of the bone is only one of these factors and not necessarily the determining one. There are cases which show considerable fracture deformity with silver-fork deviation and yet have acquired an astounding degree of utility, while others with little or no deformity are not infrequently gravely handicapped in motion. One must remember that with a fracture of the lower end of the radius, there also occur, and to a considerable degree, injuries to the soft parts, especially tears of the muscle tissue and hemorrhage into the tendon sheaths lying anteriorly to the fractured bones. The organization of such blood clots in tendon sheaths has a great deal to do with the later disability of the wrist. It ties up the flexor tendons and prevents their free action. There is further to be considered that Colles' fracture, just as the injuries in the wrist itself, is often followed by secondary traumatic arthritis. This latter factor, much more than the original injury itself, determines the degree of disability. The muscles of the forearm undergo shrinkage and degeneration, the tendons become adherent, and the circulation is usually very considerably disturbed. It is easy to see that the age of the patient will be of great influence upon the outcome of the fracture deformity. Old people are extremely prone to develop traumatic arthritic conditions in the wrist and degenerative changes in the muscles and tendons. For this reason, one need not be surprised to find a great deal of discrepancy between the deformity present and the amount of disability directly and indirectly resulting therefrom.

The writer's series covers 15 cases of Colles' and forearm fractures ranging in age from 15 to 67 years, and, in duration of the deformity, from 3 weeks to a year following injury.

Considering the cases of fracture deformity of the radius of more than two months' duration, we have then 6 cases with considerable deformity. Of these 6 cases, 3 had poor function, and 3 good function. There were also 5 cases, with moderate, slight, or no deformity, among which function was poor in 2 cases, fair in 1 case, and good in 2 cases. This shows that the degree of the deformity is not in keeping with the degree of disability.

On the other hand, there were 6 cases over forty years of age; of these, function was poor in 5 cases, and fair in 1 case, in spite of the fact

that 5 of the cases had either only very slight deformity of the wrist or none at all.

TABLE OF DEFORMITIES FROM COLLES' AND FOREARM FRACTURES

Name	Age in Years	Duration	Deformity		Mode of Injury	Degree of Deformity	Function
B. M.	23	1 yr.	Colles' fracture:	backward displacement	blow	considerable	good
P. K.	26	6 mos.	Colles' fracture:	posterior displacement	fall	considerable	poor
K. U.	63	3 mos.	Colles' fracture:	anterior displacement	hyperextension	considerable	poor
E. S.	48	3 mos.	Colles' fracture:	posterior displacement	hyperextension	moderate	poor
O. H.	18	10 mos.	Colles' fracture:	posterior displacement	blow	slight	fair
A. M.	19	2 mos.	Colles' fracture:	posterior displacement with subluxation of ulna	hyperextension	considerable	poor
K. W.	20	5 mos.	Colles' fracture:	posterior displacement with subluxation of ulna	hyperextension	considerable	good; almost full motion
F. W.	51	1 yr.	Colles' fracture:	None	hyperextension	none	poor; atrophy scarbound tendons
E. B.	67	2 mos.	Colles' fracture:	posterior displacement	hyperextension	very slight	poor; stiffness of fingers and wrist
K. C.	60	5 wks.	Colles' fracture:	posterior displacement	hyperextension	slight	poor
J. K.	20	6 wks.	Colles' fracture:	posterior displacement	hyperextension	slight	poor
L. O.	45	3 wks.	fracture of the ulna		blow	slight	fair
A. K.	30	8 mos.	fracture ulna; nonunion		fall	none	poor
E. P.	15	1 yr.	fracture forearm bones:	posterior displacement	hyperextension	considerable	good
L. F.	18	8 mos.	fracture of the radius		blow	none	good

In the treatment of fracture deformities of the forearm and wrist, the medicomechanical after treatment plays a most important part. This should begin at the earliest possible moment within eight or ten days after the injury and should be continued until motion has been restored to the fullest possible extent.

Fracture Deformities of the Fingers.—Chronic deformities following fractures of the fingers often lead to disabilities because of the involvement of the neighboring joints. Traumatic arthritis also plays a

considerable part as complicating the original deformity and interfering with the function of the joint.

The treatment of the fracture deformity is principally medicomechanical and consists in early and persistent active and passive motion of the joint involved and in massage of the muscles governing the action of this joint. In the phalangeal joints, stiffness can as a rule be overcome by continuing the mechanical after treatment for a period of from four weeks to three months.

In several cases of fracture deformities of the fingers of the writer's observation, the physiological motion was restored readily by means of massage and active and passive motion. One case of fracture deformity of the thumb had to be operated upon because of its complications. The case was one of the injury to the thumb eighteen months previously, which resulted in the fracture of the basal phalanx and also in backward and ulnar displacement of the end phalanx. In this case, the resection of the head of the basal phalanx had to be undertaken in order to reduce the dislocation. Good function of the phalangeal joint of the thumb was obtained and this persisted during one and one half years of observation.

Fracture Deformities of the Elbow—*Cubitus Valgus.*—A traumatic cubitus valgus is often observed as a result of fracture deformity of the elbow involving the external condyle. In the normal individual, the carrying angle of the elbow is 10 to 15° in men and 20° or more in women. A considerable increase in the carrying angle in women takes place during puberty owing to the increased width of the pelvis. The anatomical basis of the normal angulation is, according to Huebscher, not a slanting position of the articular end, but rather a lateral curving in of the lower end of the humerus. In the pathological cubitus valgus, this carrying angle is increased by the deformity, which is caused, most commonly, by the fracture of the external condyle of the humerus. Cases of cubitus valgus from occupational strain, such as exercise or lifting, have been reported by Schwartz, but it seems that a certain natural predisposition (laxity of the lateral ligaments) is necessary in order to bring about a cubitus valgus deformity following mild occupational strain.

Bonnet reported 3 cases of cubitus valgus in paralysis of the median and ulnar nerves; the deformity in these cases was due to the disturbance of muscle equilibrium, incident to the loss of the flexor muscles arising from the inner condyle. In paralysis of the median alone, the flexor carpi ulnaris is the only one to persist, but it is sufficient to counterbalance the muscles coming from the outer condyle. In paralysis of both nerves, however, the action of the extensor group, coming from the outer condyle and the external edge of the humerus, brings about unopposed abduction of the forearm.

Traumatic Cubitus Varus.—The cubitus varus is a frequent deformity following fracture of the elbow joint. The most common single type of fracture leading to this deformity is the fracture of the internal condyle

or the intracondyloid fracture of the humerus. The factor determining the disability is not so much the lateral deviation of the elbow joint as the displacement of the fragment in front or behind the line of the joint.

Of 5 cases of cubitus varus observed, 2 were fractures of the internal condyles, 2 were fractures of the outer condyle, and 1 was on intracondyloid fracture. The deformity was brought about by fall upon the elbow in extension in 3 cases and the function was good in 4 of the 5 cases. In 1 case, the fracture had led to a partial ankylosis of the elbow with poor function; this was due to extra-articular adhesions rather than to displacement of the condyle, since the latter was displaced directly lateralwards.

The treatment of the cubitus varus deformity, as such, is entirely surgical, and consists in the osteotomy of the humerus immediately above the elbow joint. In the one case in which such osteotomy was performed, the result was a restoration of the normal carrying angle. In the other cases there was not enough deformity to warrant the operation, since the function of the elbow was not impaired (Plate XLV, 1, 2, 3, 4).

Elbow Strain.—This condition should be differentiated as a distinct clinical entity. It is caused by a sprain of the extensor muscles of the forearm which originate at the external condyle of the humerus. The lateral ligament of the elbow, spreading out fan-shape from the external epicondyle and serving as point of insertion for the extensor muscles, is sprained or torn. There is, therefore, direct pressure pain at the external epicondyle of the humerus. But the deep fascia of the forearm which also becomes aponeurotic, serving as tendon of insertion to the anconeus quartus, the extensor carpi radialis and ulnaris, the extensor digitorum communis, and the extensors of the fifth finger, consequently participates in the muscle strain; the result is tenderness of the extensor surface of the forearm distally from the external epicondyle. It is important to know that these sprains of the elbow may not only come about by direct or indirect trauma, but that they may also occur as occupational disturbances caused by continued and gradual strain upon the extensor muscles. They have received occasional attention under the name of joint neuralgias (epicondylalgia of Ramak and Bernhardt), while Oppenheim regards them as occupational neuroses.[2] The treatment of this condition is fixation in splint or cast followed by massage.

Traumatic Ankylosis of the Elbow.—Fracture deformities of the elbow resulting in ankylosis are frequent. It is usually the intracondyloid or supracondyloid fracture of the lower end of the humerus which leads to the deformity and ankylosis. A displaced fragment is very often found in front of the elbow joint and is then the cause of considerable restriction of the flexion range of motion. The bony obstacles are, however, by no means the only, nor are they usually the principal, sources of the functional difficulties. Very extensive and very strong extra-

[2] Tennis elbow is a condition of elbow sprain recently described by Osgood. He believes that the occasional strains of the external condyle cause the inflammation of bursae situated in this space, which produces some of the symptoms.

LEGEND FOR PLATE XLIV

Fig. 1.—G. W. Fracture Deformity of Elbow.

Fig. 2.—G. W. X-ray before Treatment.

Fig. 3.—G. W. After Arthroplasty.

Fig. 4.—G. W. X-ray after Operation.

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LEGEND FOR PLATE XLV

Fig. 1.—V. W. Cubitus Varus Traumaticus.

Fig. 2.—V. W. X-ray before Operation.

Fig. 3.—V. W. After Operation.

Fig. 4.—V. W. X-ray after Operation.

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articular adhesions are quite regularly found in front of the elbow joint. They are the result of the organization of the considerable hematoma which follows the injury of the soft structures surrounding the joint. They determine as a rule much more the ultimate restriction of the range of motion than does the displacement and interposition of the fragments themselves.

Where the ankylosis is due mainly to periarticular adhesions, the treatment must take into consideration the extent to which the fibrous strand may be overcome by mechanical means. There is a possibility of recovering by conservative treatment, both in children and in adults, a certain amount of motion, if there is no grave intra-articular destruction of the joint surface. The treatment must be carried out with the proper amount of judgment and caution, in view of the reaction of the soft tissues to forcible manipulation. The position of the elbow joint in cases in which the articular surfaces have remained intact is then dictated by muscular contracture and by the extra-articular adhesions; a relaxation of the contracted muscles of the elbow joint may be often obtained by fixation. When mobilizing procedures are in order, passive manipulations should keep pace with active motion. If a fragment is wedged in front of the elbow joint, it can be dissected out without materially interfering with the integrity of the joint itself, and postoperative mechanical treatment and mobilization of the elbow joint is to follow within a week or two after operation.

Case Reports.—J. F., 16 years old. Fracture of the left elbow 5 years ago. Inability to extend the elbow. Examination shows the lateral condyle detached from the outer side of the humerus, to a point in front of the elbow joint where it can be felt under the skin. The extension of the arm is checked at 150°, the flexion at 80°. The detached piece of the external condyle was resected and so were the adhesions in front of the elbow joint. The arm was placed in a plaster-of-Paris cast for two weeks and then the mechanical after treatment was started. The elbow obtained its full range of motion.

A. K., 13 years. Fracture of the elbow ½ year ago. Examination shows flexion of the elbow checked at right angle. The X-ray shows fracture of the lower end of the humerus, the upper fragment being displaced forward. The lower end of the upper fragment was resected, and a series of casts applied, with the result that the range of motion reached from 145 extension to 45 flexion, or 100°.

M. W., 12 years. Fracture of the elbow 5 months ago. There was ankylosis of the elbow at the angle of 130°. No flexion or extension, but free pronation and supination. The X-ray showed intracondyloid fracture, the inner condyle being displaced forward and inward so as to form a bony prominence in front of the elbow joint, preventing flexion. The lower end of the humerus was resected as well as the adhesions in front of the joint. The range of motion was then from 45° to 160°, equaling 115°. The arm was put up in flexion. In this case, most of the motion gained by operation was lost for a time by early interruption of plaster

fixation, and the premature and too vigorous beginning of the after treatment. But after application of the cast, the loss of the motion was made up to a large extent.

B. G., 35 years. Fracture of the elbow 5 months ago. X-ray shows fracture of the external condyle of the humerus which is displaced forward in front of the elbow joint. At operation, the external condyle was resected and the numerous adhesions were freed. The motion of the elbow, which before the operation was limited to 20°, was then increased to range from 80° to 160°, or 80°. In this case, although the after treatment was instituted almost immediately after operation, progress was slow because of muscle contracture which considerably resisted the application of active and passive motion, so that in the end the gain in motion was rather limited.

Experiences of only partial result after removal of existing mechanical obstacles in the elbow have taught us two things: first, that it is possible by too vigorous and too early after treatment to lose some of the motion regained at operation, due to the reformation of extra-articular adhesions. This would lead to the adoption of more conservative means and possibly to a prolongation of the fixation treatment after operation. On the other hand, in several cases, we could not escape the impression that the resection of bone at operation was not sufficient to insure free motion of the joint, and that, possibly, a more radical procedure would bring about more uniform results. Arthroplasty, we believe, should be done more often in the latter group of cases.

Altogether, 19 cases of ankylosis of the elbow joint upon traumatic basis were observed.

Arthroplasty of the Elbow Joint.—The first arthroplasty on any joint was performed by Helferich in 1893; the next by Miculicz in 1895; both on temporomaxillary joints, and in both cases temporal muscle flaps were used. Gluck (1892) used skin flaps and Schumski nonabsorable material of zinc, rubber, celluloid, and silver.

The method of arthroplasty received the greatest impetus with the introduction of soft tissue interposition. Murphy in 1905 introduced the fascia flap in this country.

In the upper extremity, the elbow is the most suitable joint for arthroplasty. Arthroplasty of the shoulder joint is seldom indicated because of the excellent function that can be obtained from a stiff shoulder joint in suitable position. For the same reason, the arthroplasty in the wrist joint is rarely used, not only because a stiff wrist in proper position gives excellent service, but also because arthroplasty of the wrist itself is a rather uncertain operation. According to Henderson's table covering 126 cases of arthroplasty of the elbow, the results were good in 97 or 76 per cent, fair in 21 or 16 per cent, and poor in 8 or 6 per cent of the cases reported.

Technic of Arthroplasty of the Elbow—Albee's Method.—A vertical incision is made, six inches in length, on the posterior surface of the elbow, directly over the olecranon, from two inches below to four inches

TABLE OF CASES OF TRAUMATIC ANKYLOSIS OF ELBOW

Name	Age Years	Duration	Condition	Deformity	Function	Treatment	Result
M. W.	12	5 mos.	intracondyloid fracture and dislocation of the ulna acquired by fall	cubitus varus with extension ankylosis	poor	operative resection	poor
G. W.	9	3 mos.	supracondyloid fracture with forward displacement and dislocation of ulna	cubitus varus with ankylosis in extension	very poor	arthroplasty	fair
W.M.L	12	1 yr.	supracondyloid fracture with volar displacement acquired by fall in extension	cubitus varus with extension ankylosis 20° of motion	poor	resection of fragm.	poor; gain 15°
B. G.	35	6 mos.	fracture of internal condyle with volar displacement by fall in extension	extension ankylosis	poor	resection of fragm.	poor; gain 15°
J. P.	20	8 wks.	fracture external condyle by fall in extension	partial ankylosis 70° motion		not treated	
F. R.	7	2 mos.	supracondyloid fracture with volar displacement acquired by fall in extension	ankylosis with 20° motion	poor	resection of fragm.	fair; gain 30°
MC F.	16	5 yrs.	fracture of external condyle; posterior displacement acquired by fall in flexion	partial ankylosis; 110° motion		resection of fragm.	good; gain of full motion
A. K.	13	6 mos.	supracondyloid fracture with volar displacement; acquired by fall in extension	ankylosis 20° motion	poor	resection of fragm.	fair; gain 30°
H. D.	11	4 wks.	supracondyloid fracture with volar displacement sustained by fall in extension	partial ankylosis in flexion; range of motion 80°	fair	conservative	fair; increased flexion
M. B.	9	2 mos.	supracondyloid fracture with volar displacement; by fall in extension	partial ankylosis 100° motion	good	not treated	
L. Y.	8	1 yr.	fracture int. condyle volar displacement; by fall in extension	ankylosis in flexion 15° motion	poor	not treated	
J. M.	35	4 yrs.	supracondyloid fracture; by fall in extension	complete bony ankylosis	poor	not treated	
E. D.	7	1 yr.	fracture int. condyle volar displacement by fall in extension	complete ankylosis in extension	poor	not treated	
M. L.	38	2 yrs.	supracondyloid fracture; volar displacement by fall in extension	flexion checked at 90°		conservative	fair; moderate gain of flexion
D. O.	30	20 yrs.	fracture int. condyle by fall	extension ankylosis at 130°; range of motion 100	good	not treated	
J. E.	35	4 yrs.	supracondyloid fracture by fall in extension	extension ankylosis complete	poor	not treated	
E. B.	15	9 yrs.	contracture biceps following strain	extension checked at 150°	good	not treated	
P. S.	21	2 yrs.	extra-articular lesion by fall in extension	extension limited at 160°	good	conservative	good; full motion
A. G.	25	6 mos.	extra-articular adhesions	extension limited at 150°	good	conservative	good; full range of motion

(Plate XLIV, 1–4; XLVI, 1–5.)

above (Langenbeck's incision). The ulnar nerve is displaced and retracted. The olecranon is sawed through obliquely from within outward. The bone connections between olecranon and humerus are severed with a narrow sharp osteotome. Then the olecranon with the triceps attached to it is retracted backward and the interior of the joint is exposed. If bone bridges are present between the head of the radius and the ulna, they are separated with an osteotome and the coronoid process is freed from the trochlea in a similar way. Exostoses are cut away from the head of the radius and the head itself is shaped with the rongeur to normal size. A free fascia flap is inserted and, carrying it up high to the anterior surface of the humerus, its margins are secured to the capsule on all sides. The ulnar nerve is replaced and the skin is closed.

McAusland's technic.—A U-shaped incision is made, beginning on the lateral aspect three inches above the elbow joint and passing over the middle of the olecranon and hence upward to a point corresponding to the beginning of the incision on the opposite side. The skin and superficial fascia are dissected and retracted upward. The ulnar nerve is dissected and retracted. A straight incision is made from the lateral aspect of the condyle to the opposite side crossing midway over the olecranon. The latter is sawed across and separated. In case of extensive bony ankylosis, one saws directly across the line of the joint, three-fourths through, and breaks the remainder. Capsule, fascia and ligaments are dissected back and the humerus is made to protrude through the wound. A new trochlea is rounded off with the rongeur. Then a piece corresponding to the olecranon fossa in the normal humerus is removed and the surface of the olecranon is curetted out so as to receive the new humeral extremity. The joint surfaces should fit accurately.

A free fascia flap is then obtained from the outer side of the thigh. This is placed around the humeral condyle by attaching it first to the anterior capsule and then tying it around the condyles by a purse-string suture so as to cover all raw surfaces. Fascia, ligaments and capsule are then sutured and the olecranon is replaced with strong chromic catgut. The skin is closed. No splint is used, but arm and forearm are placed on pillows and passive motion begins on the fifth day.

Ashhurst's Technic.—This method gives an excellent approach to the joint. A skin incision is made beginning at the external supracondyloid ridge of the humerus, five cm. above the joint, and is continued downward to the joint level, from which point it is curved slightly backward on the forearm. The soft parts are cleared away from the humerus. The supinator longus and the extensors carpi radiales are placed forward, the triceps backward until the external condyle is thoroughly exposed, as well as the anterior capsule of the joint and the external lateral ligament. Then the external condyle is detached from the bone with an osteotome, the section entering the elbow joint on the capitellar surface of the humerus. In most cases, even if the ulnohumeral joint is thoroughly ankylosed, the radiohumeral joint is found free. The external condyle is then turned down. The next step is the dislocation of the

LEGEND FOR PLATE XLVI

FIG. 1.—E. R. X-RAY. FRACTURE ANKYLOSIS OF ELBOW.

FIG. 2.—E. R. MOTION OF ELBOW AFTER OPERATION.

FIG. 3.—E. R. X-RAY AFTER OPERATION, SPUR REMOVED.

FIG. 4.—B. G. FRACTURE ANKYLOSIS OF ELBOW.

FIG. 5.—B. G. X-RAY. SHOWING FRAGMENT.

FIG. 6.—R. A. X-RAY. FRACTURE OF SCAPHOID.

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joint. Severing the synostoses between humerus and ulna by chisel, the joint is then dislocated by adducting the forearm around the internal lateral ligament as a hinge until the forearm is almost parallel with the upper arm and radius and ulna are coming into full view. Then the bone ends are shaped. As little as possible is done to the ulna, especially when the head of the radius is intact, reliance being placed mainly upon the resection of the humerus for the shaping of the new joint. But when ankylosis exists in the radio-ulnar joint also, then resection of the head of the radius rather than the insertion of the flap between radius and ulna is advisable. The shaping of the humerus is carried out with the Gigli wire-saw. Then the interposition of the flap is carried out. The bones are temporarily restored to normal relation, the skin incision is enlarged from the upper edge backward across the posterior surface of the arm. A flap of fat and fascia is obtained from the superficial surface of the triceps muscle with its base at the olecranon. The elbow joint is again dislocated and the flap is attached to the internal lateral ligament of the elbow, as well as to the anterior and posterior capsules.

The forearm is again restored to normal position, the external condyle is brought up in place and fixed to the humerus, the triceps is sutured to the supinator longus and the extensors carpi radiales, and the skin is closed. The method has been used by the writer to very good advantage in one case of severe fracture deformity of the elbow with ankylosis and cubitus varus deformity, and in one case of congenital ankylosis.

General Remarks on Arthroplasty.—Certain biological facts regarding tissue reaction and tissue changes in the cases operated by arthroplasty must be taken into consideration in order to appreciate the conditions upon which operative success is based.

According to Allison and Brooks, any inflammatory process of sufficient severity within a joint will result in the formation of granulation tissue, which destroys the joint cartilage and finally causes union of the denuded bone surfaces by fibrous bands. By a metaplastic process, this fibrous tissue will often be transformed into bone and then a bony union is established. It is the purpose of arthroplasty to prevent the occurrence of just such adhesions as generally take place in inflammatory and suppurative joints. From the experiments of Allison and Brooks, it is known that denuded joint surfaces are at the end of five days covered with granulation tissue which pours out of the bone from the marrow spaces and gradually develops into fibrous tissue. This is the primary stage of the osseous union and it takes only a deposition of lime salts to bring about fusion between the bones constituting the joint.

In the event of interposing fascia or other soft tissue between the bone ends, as is done in our present methods of arthroplasty, such adhesions can be prevented only if a cavity is formed between the two bone ends by the absorption of the transplanted tissue. In those instances where parts of the tissue persist, the persisting islets promote adhesions. From this point of view, then, there is no distinct advantage to be derived from the use of a pedicled flap.

Case Reports.—G. W., 12 years. Sustained a surpracondyloid fracture of the humerus 6 months ago; examination showed the elbow completely ankylotic in extension of about 150°; cubitus varus deformity. X-ray showed a fracture through the internal condyle and trochlea with displacement of the fragments upward. Dislocation of the ulna. Operation: arthroplasty of the elbow following Ashhurst's technic. An incision is made over the radial side of the lower end of humerus and upper end of forearm. The muscles are stripped off the bone, proceeding between the brachialis anticus and triceps above and the supinator longus and extensors of the wrist below. The radiohumeral joint is exposed. Then the olecranon is sawed across, and, with the triceps adherent to it, deflected upward. The joint is then entirely dissected in its internal aspect and all adhesions are resected. Then the forearm is swung around the internal lateral ligament and the bones are made to protrude through the wound. The lower end of the humerus is resected and shaped. It is then covered by a flap taken from the fascia of the posterior surface of the upper arm. This flap is fastened over the lower end of the humerus by a purse-string suture. The bones are replaced and the wounds closed. The patient did not retain entirely the initial range of motion, but he got a fair mobility, which at the present is about 40°, and under persistent after treatment is constantly improving (Plate XLV, 1-4).

Dr. C. W., 26 years. Ankylosis of both elbows following general sepsis 3 years ago. Position of the elbow is ankylosis in extension on both sides; pronation and supination free. Arthroplasties following identical technic on both elbows. A longitudinal incision was made over the inner aspect of the humerus and forearm, subperiosteal stripping of the elbow joint exposing the lower end of the humerus and upper end of the ulna; the bone bridge uniting humerus and ulna was chiseled away, so that a cavity of three-quarters of an inch long remained. Then the bone ends where shaped. A free fascia flap was interposed to cover the distal ends of the humerus and the wounds were closed. Following operation both elbows were placed in extension. Results: the right elbow has a range of motion from 108 extension to 55 flexion, or 53°, 3 months after operation; the left elbow, 105 extension to 62 flexion or 43°, after 2 months. While the range of motion is moderate, it is absolutely free and painless and shows no tendency to decrease.

F. B., 30 years. Ankylosis of the right elbow following chronic arthritis existing for 5 years. Arthroplasty of the radiohumeral joint and radio-ulnar joints to relieve pronation ankylosis as a first step of the arthroplasty of the elbow. The radiohumeral joint is reached by a lateral incision. The head of the radius is exposed and resected; a flap is interposed. Then, the lower radio-ulnar joint is also exposed, and a flap inserted between ulna and radius, after resecting a bone bridge uniting the two bones. The result of this operation was a gain in pronation and supination movement amounting to about 50° to 60°.[3]

[3] In his later arthroplasties of the elbow, the writer is using, now regularly, the posterior U-shape incision. In shaping the bone ends, one does very well to follow the practice of Putti, who carefully smoothes off the ends with files of suitable shape.

Of 4 arthroplasties of the elbow, the result was good (range of motion 50° or over) in 2 cases; fair (range of motion 40° or over) in 2 cases.

Tendon Ruptures.—The subcutaneous ruptures of tendons are rare. The tear usually occurs at or near the insertion or at the junction of the tendon of insertion with the muscle. The so-called spontaneous ruptures of tendon are hardly ever purely traumatic. As investigations, especially those covering the rupture to the biceps of the forearm, have shown, such ruptures usually involve already diseased tendons. The changes consist mainly in hyaline degeneration of the tendon, subsequent to chronic changes in the joint, especially arthritis deformans.

Ruptures of the Finger Tendons.—Of the tendons of the fingers, the one most often involved is the extensor tendon of the thumb. According to Schlatter's observation, a comparatively slight trauma often suffices to cause rupture. Van Verth reports 3 cases of rupture of the long extensor tendon of the thumb, 2 occurring in waiters and 1 in a woodcarver, both occupations involving continued and chronic strain upon these tendons. To this group, the so-called drummer's palsy may also be added, which affects the tendon of the long extensor of the thumb and is induced by the continuous strain upon this tendon.

In rupture of the tendon, the ends appear frayed, and there is a round-cell and spindle-cell infiltration in the tendon surrounding areas of hyaline necrosis. That the rupture occurs in changed tendon tissue is further shown by numerous hemorrhages seen in the masses of the tendon tissue. Stern reports 11 cases of this deformity, which, according to him, was first described by Abbe in 1894. Such causes as buttoning tight buttons, pulling the fingers, wrestling, basket ball or baseball playing, bowling, a fall upon the fingers, are known to produce the injury. These injuries are really occupational in character. In the case of the thumb extensor, the rupture is usually found at the point where the tendon appears distally to the ligamentum carpi dorsale and turns laterally to reach the first metacarpal of the thumb. In none of the cases of tendon ruptures of the extensor tendons of the fingers observed by Schlatter was there found an injury to the bone. His series embraces 9 cases of rupture of the tendon at the end phalanx or at the second interphalangeal joint.

The typical symptom is inability actively to extend the end phalanx, although passive extension is entirely free. If left to itself, the end phalanx drops into a position of flexion (drop phalangette).

In the majority of cases, immobilization restores ability of extension, although the prognosis of the conservative treatment is not always good. When operation is required, and this is the case in all instances which do not promptly yield to immobilization, the procedure is simple. The tendon can easily be picked out and fastened to the distal phalanx of the finger. Only in old cases, the place of rupture may not easily be distinguished and one may have to resort to the expedient of fastening the tendon to the capsule of the interphalangeal joint.

Case Reports.—M. M., 35 years. Three weeks ago, when reaching behind a pillow, the patient injured the extensor tendon of the index

finger of the right hand. There was evidently no violent injury and no pain. The end phalanx of the index finger was noticed to drop into flexion position and there was no power of active extension, although the end phalanx could be straightened passively. Treatment consisted in volar splint and the disability disappeared within a few weeks.

M. B., 48 years. Ruptured extensor tendons of the fingers, 6 months ago, by being caught in a wringer. Examination showed that active extension of all fingers was impaired in the end phalangeal joints. There was no fracture; the condition improved considerably after 2 weeks of massage and splinting.

Dislocation of the Extensor Tendons of the Finger.—This is an injury of rare occurrence. The statistics of Schlatter show that up to 1909 there were only 10 cases reported of dislocation of the extensor tendons of the fingers. In Schlatter's case, there was a rupture combined with dislocation of the extensor aponeurosis of the fifth finger, caused by a blow. In dislocation of the tendon, the two halves are displaced laterally. Consequently, active extension is impossible at the start; however, if the patient is helped somewhat at the beginning of extension, the remainder of the motion can be carried out actively. The treatment, in cases of dislocation of the tendon, consists in the suturing together of the two laterally displaced halves of the tendon.

Of rupture of the extensor tendons in midphalangeal joints, only 2 cases are reported, one by Maydl and the other by Schlatter. The determining factor in this injury is the state of the finger tendons at the moment the injury is received. A forcible, active extension of the joint, acting together with a violent force which tends to produce passive flexion at the same time, brings about a rupture of the tendon over the midphalangeal joints. The case reported by Schlatter was treated successfully by immediate operation and suture.

The Rupture of the Biceps Tendon.—A complete analysis of this condition is to be found in Maydl's report of 1882, as well as in later reports of Loos (1901) and of Ledderhose (1909). Observations on rupture of the larger tendons have been made as early as 1722, when J. L. Petit reported ruptures of the tendo achillis and of the quadriceps tendon. Ruptures of the biceps have been reported by Ashhurst (1873), by Poncet, Hueter, Nelaton, Jarjavay, and many others. All these ruptures came about by active exertion of the muscle.[4] The statistics of Loos show, up to 1901, 68 cases, in the literature of which 44 were muscle ruptures, 18 tendon ruptures, and 6 incomplete tears of the tendon, giving the relation of muscle to tendon rupture as 5 to 2. The typical rupture was that of the long head of the biceps, and the upper part of the tendon was ruptured in 19.5 per cent. The muscle was ruptured in 36.9 per cent and the tendon muscle line was ruptured in 43.6 per cent of the cases. Investigation into the condition of the shoulder joint in cases of rupture of the biceps almost always reveals the fact that an arthritis deformans

[4] There is also a classical rupture of the plantaris muscle of the leg, which occurs suddenly through traumatic influences.

of this joint is present. The biceps tendon is often displaced from its bed in the sulcus intertubercularis and in the majority of cases only a few strands are left of the intra-articular portion of the tendon, since the rupture occurs very near to the place of origin at upper margin of the glenoid cavity. Often the upper extra-articular portion of the tendon is adherent to the sulcus intertubercularis, being caught at times under a bony bridge.

In rupture of the tendon, there is, as a rule, considerable downward displacement of the peripheral end of the tendon. The gap amounted, in cases reported by Dreyzehner, to 10 cm. and more. With the rupture of the tendon, the belly of the biceps muscle also becomes displaced downward and this displacement becomes more distinct when the muscle goes into active contraction. There is above the contracted muscle belly of the biceps a space in which the anterior surface of the humerus can be easily palpated. The contractile power of the biceps is greatly reduced, and, naturally, its absolute strength is diminished accordingly.

It is not always the proximal tendon of the biceps muscle which is ruptured. There are cases reported which involve the rupture of the tendon of insertion of the biceps at the tuberosity of the radius. This, however, is the great exception. It has already been mentioned that the condition underlying spontaneous rupture of the biceps muscle is an arthritis deformans of the shoulder joint, the tendon taking part in the arthritic changes. In no case reported in the literature could the purely traumatic nature of the rupture of the tendon be demonstrated. According to Ledderhose, the rupture of the tendon is based upon chronic degenerative changes in the tendon itself, following chronic arthritic changes in the shoulder joint, and the trauma is only a superinducing factor. Mueller, in his careful study of the literature up to 1912, concurs in this view. He finds most conspicuous vascular changes in the tendon showing the typical picture of an endarteritis obliterans. In differentiation from muscle hernia it should be remembered that, in the rupture of the biceps tendon, contracture of the muscle increases the tumor. In true muscle hernia, on the other hand, contracture of the muscle will cause the tumor to disappear, while a relaxation of the muscle will cause the hernia to become more apparent. Nevertheless, many cases of rupture of the biceps tendon have been reported in the literature as herniae of this muscle.

The treatment of this condition is almost entirely operative. Only in rare instances of incomplete rupture, immobilization of the muscle and bandaging may result in a union of the tendon. The great majority of the cases require operation. This consists of longitudinal incision in the interspace between the deltoid and pectoralis muscles, and the dissection of the peripheral end of the tendon. This procedure is not always an easy one, since the tendon is often pulled out of the sulcus intertubercularis and curled up or reflected backward. The securing of the central end of the tendon is always fraught with considerable difficulties and, since the rupture takes place near the origin, the finding of the central

end requires the opening of the shoulder joint. Most observers, however, do not consider the opening of the shoulder joint a proper procedure, and content themselves rather with fastening the peripheral end of the tendon back to its sheath in the intertubercular sulcus.

Case Report.—H. J. S., 21 years. Traumatic rupture of the biceps. seven weeks ago, the patient was caught in a log chain hook receiving an extensive lacerated wound of the left arm, and a partial rupture of the biceps muscle. The wound healed kindly and there were no complications. At the examination, the biceps could be palpated at the anterior aspect of the upper arm, but on contraction it did not have normal configuration and was considerably indurated. There was no interference with free contraction and all motion was normal, except for a moderate weakness of the elbow flexion in comparison with the other arm. This was a case of purely traumatic rupture of the biceps. No treatment was indicated.

Of the muscles of the upper extremity, tendon ruptures have been observed in the trapezius, the deltoid, and the pectoralis major, in rare instances. Tears of the tendons of insertion of the latissimus dorsi and pectoralis muscles, however, are not uncommon. The symptoms caused by muscle tears of the inward rotators of the arm, especially of the pectoralis major and latissimus dorsi, can be differentiated from other periarticular lesions of the shoulder joint by the location of the tenderness and the peculiar restriction in motion. These conditions have been considered in Chapter I.

Contrary to the relative frequency of tendon ruptures of the extensors of the fingers, ruptures of the flexor muscles of the fingers are extremely rare. Haessler reports a case of rupture of the flexor profundus of the fourth finger and, in a case of Schlatter, a rupture occurred in the flexor profundus of the little finger. In the latter instance, the tendon was found curled up in its tendon sheath and could be sutured back into place. Another case of rupture of the flexor profundus tendon of the fourth finger cured by suture is reported by Lessing.

Habitual Dislocation of the Shoulders.—Habitual dislocation of the shoulder often follows injuries producing relaxation of the capsule. The tears of the rotators are often held responsible for this condition, but of the greatest influence is the condition of the capsule, especially the anterior and the inferior portion. Muscular conditions, such as muscle atrophy, have often been found responsible for the habitual dislocation (Burrel and Lovett, Clairmont, Ehrlich); but it seems that a relaxation of the inferior of axillary portion of the capsule is a most important element for the usual type of the subcoracoid habitual dislocation.

The mechanics of this condition have been studied extensively by T. T. Turner, who believes that the extreme motions of the shoulder tend to force the humeral head out of the socket, but are checked by the tightening of the capsule on the opposite side of the joint. In his opinion, it is in abduction and outward rotation that the resistance of the capsule is broken in its axillary portion and the head escapes from the socket

into the axilla, forcing the torn capsule margins apart with each repetition of the dislocation. These torn margins of the capsule are separated and, finally, they cicatrize together across the gap, forming in this axillary portion of the capsule a cicatricial piece which prevents the capsule from tightening up and makes the subsequent escape of the head from the socket more easy.

Sever, while recognizing the relation of the capsule to the habitually dislocated head, points out that the ligamentous capsule of the shoulder joint is a rather feeble and very lax structure, and that the shoulder owes its stability to its muscular capsule, formed by the subscapularis, supraspinatus, infraspinatus, and teres minor muscles. The only portion of the joint capsule which is not guarded by muscular origins or insertions is that between the origin of the triceps at the lower edge of the glenoid fossa and the insertion of the subscapularis above. It is indeed in this portion where the capsule is more frequently torn and, as a result of these primary tears, there exists a relaxation of this portion of the capsule which allows subsequent and recurring dislocations. Therefore, it is argued, when the muscular control of the capsule is diminished, relaxation of the capsule will be enhanced and followed by subsequent recurring dislocation. The muscles which are mainly involved in the securing of the head in the socket are the subscapular muscle and the supraspinatus.

From this point of view, the newer methods of operation applied in this condition may be considered.

Clairmont and Ehrlich form a small flap from the posterior portion of the deltoid with an upper basis. This muscle flap is carried midway around the neck of the humerus, then forward, and is there sutured to the capsule. The method used by Burrell and Lovett (1908) is very efficient. An incision is made over the coracoid process and extended downward following the line of the cephalic vein. The latter is drawn inward and the deltoid and pectoralis muscles are separated in their intermuscular septum. Then the coracobrachialis and short head of the biceps come into view in the upper end of the wound and the insertion of the pectoralis major in the lower angle. Head and neck of the humerus can now be exposed by blunt dissection.

The anterior and internal aspect of the capsule is now exposed; the latissimus dorsi and pectoralis muscles being drawn inward, the subscapularis tendon is divided and the muscle retracted upward. With the arm in abduction of 25°, one obtains the best exposure of the relaxed capsule. Then the relaxed part of the anterior and inferior capsule is grasped with hemostats. Three sutures of No. 1 catgut are inserted through the fold and then an elliptical piece an inch long and one half inch wide is dissected between the sutures already placed. When the sutures are tied, the capsule is then distinctly shortened.

T. T. Thomas gives three routes by which the capsule may be exposed: the deltopectoral or external to the short head of the biceps; the antero-axillary, between the coracobrachialis and the axillary vessels;

and, finally, the postero-axillary, or posterior to the axillary vessels. He objects to the deltopectoral exposure because it is too far lateral. The antero-axillary operation gives a freer exposure than the deltopectoral route. The best route, however, is the postero-axillary incision, which gives exposure just where the changes in the joint lesion are best detected; no muscles have to be divided, and perfect drainage is possible, which is important because of the uncontrollable oozing which practically always occurs during the first twenty-four to forty-two hours. It is only necessary in this method to refrain, carefully, from injuring the circumflex nerve, which lies directly in the field of exposure. Sever considers as the essential point the suturing of the capsule. Such operations as devised by Loeffler (fascia plasty), and Schultz, as well as the bone transplants used by Eden, and especially also the muscle flap operations as devised by Ollerenshaw and by Clairmont and Ehrlich, he thinks are unnecessary; he also maintains that the success of many of the capsule plaiting operations is due to the fact that the subscapularis tendon is shortened in the process.

In order to get a clear exposure of the joint capsule, it is necessary to divide a portion of the pectoralis major as well as the subscapularis tendon. The latter is then sutured following the plaiting of the capsule. The suturing of the subscapular tendon and the dividing of the pectoralis major tendon are then, according to Sever, the two important factors and are all that is really necessary in order to control the situation. The deltoid and coracobrachialis will be able to hold the humerus in place if the pull of the stronger pectoralis major is removed and the slack in the subscapularis tendon is taken up by suture. It seems from observations made both by Sever and Thomas, that the capsular operations, either because of the plasty of the capsule itself or because of the muscle suture incident to it, offer at present the best results in the operative treatment of the recurrent dislocation of the shoulder.

In his latest report, T. T. Thomas gives the results of 42 operations. On the 24 shoulders operated in nonepileptics, only the capsule operation was performed, and in 13 cases there was no dislocation since operation, which had occurred between 3 months to 13 years prior to the report. In 18 cases of shoulder operations in epileptics, the capsule operation was done in all but 1 in which a high excision of the neck of the humerus was performed to stop the recurrent dislocation. Taylor records 11 cases of complete success after a period of from 4 years to 11½ years. Only 2 cases were to be classed as failures, and 2 showed good results after a second capsular operation.

Chronic Dislocation of the Radio-ulnar Joint.—Isolated dislocation of the radio-ulnar joint was first reported by Desault in 1777, and according to the statistics of M. Sterne (1919), 31 volar and 18 dorsal dislocations of the lower radio-ulnar joint have been described. It has been an old teaching of Malgaigne that the volar dislocation of the radio-ulnar joint is caused by forced supination, and the dorsal dislocation by forced pronation of the forearm.

In order to prevent confusion, it is necessary to exclude the dislocations of the lower radio-ulnar joint which occur in Madelung's deformity as well as those which occur at times in arthritic wrists and which have been mentioned in Chapter VIII. Only those dislocations which are caused by direct violence are here considered. The mechanism producing ulnar dislocations is, according to Sterne, as follows:

Forced dorsiflexion of the wrist causes a volar dislocation of the ulna.

Forced volar flexion of the wrist causes dorsal dislocation of the ulna. The latter statement is in keeping with the observation of dorsal dislocation of the ulna occurring in the forced volar flexion in arthritic wrist joints.

Forced pronation causes dorsal dislocation of the ulna; forced supination causes volar dislocation of the ulna.

Pronation of the hand with the forearm fixed, or supination of the forearm with the hand fixed, causes volar dislocation.

On the other hand, supination of the hand with the forearm fixed, or pronation of the forearm with the hand fixed, causes dorsal dislocation.

The treatment of the condition consists in reduction of the dislocation and reefing of the capsule. A fascia strip may be used to reinforce the capsule and guard against recurrence.

Dislocation of the Head of the Radius—CASE REPORTS.—L. V. K., 6 years. About 3 months ago, while playing, patient fell and hit his elbow. Another fall followed 10 days later. At this time, a dislocation of the head of the radius was found. The examination of the elbow showed that the flexion stopped at 75°, while extension in the elbow was almost complete, lacking only 10° to 15°. In supination it was easy to push the head of the radius into its place in contact with the capitellum of the humerus, but when the forearm was pronated, the head of the radius promptly circled around the ulnar half of the capitellum in front until it could be felt almost in the middle of the cubital fold. It appeared that, with the stretching of the biceps tendon, the head regularly pulled out of its connection with the humerus so that the only position in which it is safe is that of flexion of the elbow and supination of the forearm.

L. T., 12 years. The patient was struck on the elbow, 6 or 7 years ago, by a bottle hitting the outer side of the elbow. The examination showed the forearm in pronation; no active supination was possible. The X-ray showed a dislocation of the radius forward.

F. J., 6 years. Dislocation of the head of the radius following birth-palsy. Dislocation of the head of the radius was caused by the pull of the biceps tendon which forced the head of the radius out of its contact with the capitellum into the lateral aspect of the cubital fold where it could be felt readily under the extensor tendons. This case was operated, and the head of the radius resected, the neck being held in place by a fascial strip. During the short observation of the patient, no recurrence of the dislocation was observed.

The Snapping Shoulder.—This is a rare condition which must be separated distinctly from habitual dislocation or subluxation of the shoulder. The contributions of Kappis have done much to promote our knowledge of the underlying pathology. The principal point in the snapping shoulder is that the whole joint moves under the deltoid muscle or, one may say, the deltoid muscle glides over the whole joint much in the fashion in which the tensor fasciae glides over the greater trochanter of the hip joint in cases of so-called snapping hip. The symptom of snapping is elicited by the contraction of the scapulo-humeral muscles. The humerus is fixed against the scapula and the entire joint moves as a whole under the deltoid muscle. In habitual dislocation of the shoulder, on the other hand, there exists a true dislocation in which the humerus leaves the glenoid fossa either partially or totally. The typical snapping of the shoulder has been observed, according to Kappis, in 9 cases, some of which were classified as habitual dislocations. The snapping occurs regularly when the joint is moved under the lateral portion of the deltoid and only 1 case of snapping of the anterior fibers of this muscle has been observed. It is possible that a number of the cases reported were actually complicated with posterior subluxation. In 1 case reported by Reich, there existed a fissure between the short head of the biceps and the insertion of the coracobrachialis muscle.

One case was observed by the writer, which might be classified as snapping shoulder. The patient, 21 years old, complained of pain in the left shoulder for 5 years after he had been hit by a baseball over the tip of the acromion. The pain originally lasted only 3 or 4 days. However, 7 months later the pain recurred on movement. It came on in attacks, which have repeated themselves at regular intervals. When examined, it was found that the head of the left humerus protruded in front slightly more under the deltoid muscle than did the right head. The patient was able to carry out abduction to 45° without discomfort. From then on, however, abduction was considerably impaired, the head coming distinctly into relief, and, when abduction reached about 90°, it was accompanied by a jarring of the head underneath the deltoid muscle. As soon as this was accomplished, further abduction became quite easy and painless. There was distinct tenderness of the deltoid muscle over the outer circumference of the humeral head.

The distinct jarring of the head at a point of 90° abduction would seem to place this case in the group of the snapping shoulders and not in that of habitual dislocation or subluxation. There was at no time any change in the relation between the humerus and the glenoid fossa. From the history, it appeared that the injury produced certain changes in the fibers of the lateral portion of the deltoid, as well as a relaxation of the capsule, with the result that the shoulder joint sagged forward under the fibers of the deltoid and had to be manipulated back, so to speak, before the upper circumference of the head could submerge under the muscular cover of the deltoid muscle.

Snapping Elbow.—Typical snapping phenomena of the elbow have been reported by Juengling in 2 cases of his observation. In these, the snapping sign was elicited by displacement of the radial head and the condition therefore should rank among the habitual dislocations of the head of the radius. Both cases were treated by operation. In one case, formation of the new socket of the radius was found in which the head moved as in a hinged joint. Two cases of habitual dislocation of the head of the radius are found described above.

Snapping Finger (Trigger finger; Doigt â ressort).—The first report of snapping fingers dates back to Notta (1859). Schilling, in 1901, reports 34 cases in the literature, while Hiller, in 1908, found 161 cases. Of these, 41 concerned the thumb, 47 the middle finger, 12 the index finger, and 44 the ring finger.

The anatomical causes underlying the condition of snapping finger might be divided into changes of the tendon, of the tendon sheath, and of the capsule and ligaments.

Among the changes of the tendons are to be mentioned tendon duplications, tendon bulbs, fibroma of the tendon, tears of the flexor sublimis at the bifurcation, and tumors and hyperplasias of the tendon.

Among the changes in the tendon sheath, there have been observed hypertrophic villi of the sheath, thickening of the tendons, fibrous strands and fibrous deposits, fibromas of the sheath, and foldings or duplications of the sheath.

Capsular ligamentous changes were cartilage ridges, or joint ridges, and changes in the lateral ligaments.

The principal symptom of the snapping finger is the snapping sign of the finger which occurs when the finger is flexed to a certain angle. At this point further flexion of the finger is carried out only with distinct effort and with an appreciable jar or snap. At the moment of snapping, pain is felt in the palm of the hand. Often the help of the other hand is necessary to flex the finger over the critical point, but when this is once overcome flexion is concluded without great effort.

In extension a similar difficulty arises again at the same point at which the flexion had been locked. In order to complete extension, a distinct effort is also necessary to overcome the apparent obstacle. Again the characteristic jerk appears, sometimes with an audible click, and extension is completed.

If the obstacle is not great, motion is painless. Often, however, especially in the beginning, pain is considerable and is usually referred to the volar surface of the metacarpophalangeal joint. It is here where one often notices a sensitive tumor of the size of a millet or pea.

Case Report.—Mrs. J. T. C. The patient complains for several months of pain in the palm of the right hand over the 3d metacarpophalangeal joint. There is difficulty in flexing this joint. At a certain angle, the fingers seem to be locked by an obstacle which can be overcome only with considerable effort. At this moment, a distinct snapping occurs, and it is repeated in extension movement as soon as this point is

reached. There is a spot in the palm over the joint which is tender to pressure, and here the snapping can be felt distinctly.

The treatment of this condition consists in massage, manipulation and splinting in earlier cases. One of the cases observed was that of a baby a few months old in which the middle finger showed a distinct snapping over the midphalangeal joint when an angle of about 60° flexion was reached. The phenomenon disappeared after a short period of splinting. In cases not yielding to massage and splinting, the operative procedure is indicated. This consists, essentially, of an incision opening of the tendon sheath, and the removal of the cause of constriction either in the tendon or tendon sheath or in the joint or capsule. Such operative procedures have been reported by Hildebrandt, who removed the spindle-shape thickening of the tendons and cured his case.

Poulsen compiled the following statistics in regard to the operative and necropsy findings of this deformity:

Of 64 cases so examined, changes in the tendon itself were found in 26 cases. Changes in the tendon sheath with tendon normal were found in 13 cases. Changes of both tendon sheath and tendon were found in 16 cases. Joint changes were found in 6 cases and no changes were found in 3 cases.

Writer's Cramp—Case Report.—J. G., stenographer: complains of cramping of the muscles of the right hand after writing for some time. This has been followed lately by weakness in the hand which is especially noted in the grip between the thumb and index finger. Examination showed distinct weakness in the adductor of the thumb and in the opponens muscle. The treatment consisted in rest, massage, and the use of appropriate penholders.

According to Benedict, a spastic and a paralytic form of writer's cramp may be distinguished. In the spastic form, clonic and tonic cramps appear most frequently in thumb and index finger, which, in the case of the thumb, causes it to be drawn forcibly against the palm in a position of flexion.

The case described above is of the paralytic form which manifests itself in a sensation of fatigue of arm and hand, making it impossible to use the hand in writing. To this is added, by some authors, the tremor form of writer's cramp characterized by tremor of the entire hand, which increases gradually and makes attempts at writing impossible. All three forms are characterized by the fact that the trouble appears only when an attempt is made to write, or soon after the beginning of writing, and that there are no symptoms in the intervals of rest except a slight sensation of ache in the arm and forearm.

Hoffa thinks that the prognosis is, in general, unfavorable and that even after several months of rest the trouble usually recurs. The treatment consists in massage of all the muscles of the extremity, beginning with the lumbricales and interossei and ending at the muscles of the shoulder girdle. When the writing is resumed, it is well to use spe-

cially constructed appliances which hold the pen. Of these, the appliances of Nussbaum, Buchheim, and Cazenave, are the best known. These contrive to eliminate the action between thumb and index finger altogether by the use of a bracelet encircling these fingers (Cazenave and Zabludowski), or they consist in a ring or ball for the palm of the hand, to which the pen is attached, the finger pressing against the ball.

Neural atrophies of the hand have been described by Ramsey Hunt. The motor type of neural atrophy of the hand is characterized by an absence of sensory symptoms. Hunt distinguishes a hypothenar and a thenar type. The former is caused by compression neuritis of the deep palmar branch of the ulnar nerve. This branch supplies all of the hypothenar and palmar muscles as well as the dorsal interossei, also the third and fourth lumbricales and the adductor pollicis. Soon after its origin, the deep palmar branch passes between the tendinous origins of the abductor and flexor brevis of the fifth finger. Again, this nerve is compressed at the point where it winds its course beneath the hook of the unciform bone. This form of palsy develops without accompanying pain, paresthesia or anesthesia in the ulnar nerve distribution. On holding out the affected hand, the fingers cannot be completely extended (interossei), a slight flexion persisting in all fingers, but especially in the fourth and fifth, where the lumbricales are also involved. The index and little fingers are held somewhat in abduction, while the third and fourth remain in close apposition.

The second type is the thenar palsy, a compression neuritis of the thenar branch of the median nerve, entirely motor in character. This is also an occupation neuritis due to overstrain of those muscles which tend to the play of the thumb. It is easily recognized by the characteristic limitation of the atrophy to the abductor pollicis, flexor pollicis brevis (outer head), and opponens pollicis. The general usefulness of the hand is not greatly impaired except for finer movements, such as writing. It is to be considered whether or not some, if not all, of the cases of writer's cramp are to be classed under the thenar type of atrophy of the hand. Hunt thinks that the prognosis is favorable if the causative factor, which is usually an occupational one, is discovered at an early stage and removed. The writer has observed 1 case of this type.

Case Report.—J. S., 18 years, complained of weakness of the muscles of the hand for about half a year. The examination showed thenar palsy with no loss of sensation, but with distinct atrophy of the muscles of the thenar and weakness of the hand. According to the statement of the patient, the trouble was not progressing. No distinct occupational factor was found causing the palsy but directions were given to avoid strain.

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CHAPTER XI

PHYSIOTHERAPY OF THE UPPER EXTREMITY

With the correction of deformities and the restoration of anatomical alignment, only part of the work of reconstruction is accomplished. As a living organ, the locomotor apparatus, once disturbed, requires more than anatomical repair to take up anew the function for which it was destined. And in the same measure as the repair of alignment and form are based upon anatomical facts, so must functional repair have its physiological and biological foundation.

Out of this need for physiological methods of repair, physiotherapy has come into existence. It means the development and reëducation of impaired muscles, the increase of muscle tone, the stimulation of retarded muscle action, the toning down of irritative and hypertonic muscle action, the overcoming of muscular contractures. It further means the development of circulatory balance, the overcoming of contractures of all kinds of tissues, and many other problems. In the field of reconstructive surgery of the upper extremity, it has the widest possible application, from which hardly any type of case is exempt.

The principal object of physiotherapy is, then, to open up physiological channels of motions blocked temporarily by disability. This object it pursues by mechanical means, by massage and manipulations, as well as by active movements which utilize the progress made by mechanical means and further its development. This is the task for the mechanotherapeutic side of physiotherapy.

Its further aim is the coördination of elementary movements, advancing the primitive motions to more complicated ones and the latter to purposeful manipulations, and finally to crafts and handwork; Muscle education and occupational therapy.

The analysis of the ordinary routine motions in life into their elementary constituents (kinesiology), both physiological and anatomical, is based upon the development of a rational system of either mechanotherapy or muscle education of the upper extremity.

KINESIOLOGY AND MECHANOTHERAPY

Elementary motion must not be construed to mean the play of a single muscle or even a single muscle group, but a selection of primitive and simple movements which may serve as a starting point to develop the more complicated ones. We know that no motion is possible in

any joint without the action of the antagonistic muscles which work in the opposite direction. For instance, in the elbow, flexion as a simple motion cannot be conceived of without the check of the extensors of the elbow, because this check alone is able to provide the timing of the motion and its uniform velocity, which is an essential part of any coördinated motion. In the same way, one could not conceive of the simple motion of abduction of the arm by the deltoid muscle without the action of other muscles which stabilize the humerus against the glenoid fossa. We have, in these instances, two apparently simple motions carried out by only one or two muscles actively, but in which, secondarily, a number of muscle groups are involved. An example of complicated motion is the rotatory motion of the shoulder joint in which a number of different muscle groups come into action in regular succession. When the details of gymnastic technic are gone into, an attempt will be made to analyze these motions into their elementary parts, but it must be understood that even then the so-called elements are still things of considerable complexity. Upon the basis of the analysis of movements, then, the reconstruction of the normal motions will have to be undertaken. On the other hand, elementary analysis will also be of service for the development of sustitutionary motion, a type of motion not usually used in common life, but which is physiologically open to development and must be called upon to serve in the case of deficiencies of the muscles originally charged with the respective movements. It is erroneous to believe that such substitutionary motions should be left entirely to the instinctive faculties of the individual afflicted. They can be developed systematically, and for this reason some space is given in this chapter to the technic of developing substitutionary motion.

Shoulder—*Scapular Muscle Exercises.*—The starting point for the exercises in this direction is the so-called neck-firm position, the arms being held elevated to the horizontal, the elbows flexed, the hands resting against the back of the neck; from this position, rotatory motion of the shoulder may begin with the contracture of the trapezius muscle and the elevator anguli scapula. In this position, it is mainly the third and fourth part of the trapezius muscle which hold the shoulder back in correct position. The first and second lift the shoulder-blade and the lower part of this muscle anchors the scapula firmly against the spinal column. In the upright position, only the upper part of this muscle will be seen to contract, but when the body is bent forward, all four parts contract, lifting the shoulder, while the lower fibers of the muscle relax as the upright position is again assumed. In this position, the rhomboid muscles act as a check modifying the upward motion. When the shoulder-blade is brought forward in position of elevation, then the serratus magnus comes into play, together with the anterior fibers of the trapezius. Both these muscles tend to rotate the scapula, causing the lower inferior angle to move outward. But in forward motion of the shoulder-blade, this action can be checked by the pull of the

rhomboid muscles, which hold the vertical border of the scapula parallel to the line of the spinous processes. In downward movements of the shoulder-blade, the inward tendency of the scapula and the downward movement of its lower inferior angle can be checked by the pull of the serratus magnus and the trapezius. Also, in downward movements of the shoulder-blade, the depressors of the arm come into play, that is, the latissimus dorsi and pectoralis muscles. In forward bending of the scapula, the pectoralis minor is the principal agent. In muscular individuals, the play of the different muscles of the scapula can be seen very distinctly on rotatary motion.

Exercises of shoulder movements should be practiced systematically. They are of excellent value as preoperative and postoperative exercises in arthrodesis of the shoulder joint, and they are, of course, of great importance in developing other substitutionary motions for the arm. It is necessary to control the posture of the patients closely when elevatory and rotatory motions of the scapula are carried out. There is a tendency to incline the head toward the side of the elevated scapula when elevation of the arm exceeds 135° because of the pull which the trapezius exerts upon the head and the cervical spine. Equilibrium must be maintained strictly by preservation of the symmetrical posture and also by development of muscles antagonistic to the contracting muscles, in this case, the trapezius of the other side.

Elevation Exercises of the Arm.—The patient stands in upright position and is made to elevate the arm slowly first in a frontal then in a forward diagonal, and, finally, in the backward diagonal plane. When these exercises are carried out against resistance, they will bring out the action of the respective muscles to good advantage. In the frontal plane, elevation of the arm is possible to 90°; in the forward diagonal planes, up to 120°; in the backward diagonal plane to 45°, without rotating the scapula. The fibers of the anterior part of the deltoid having the most favorable angle of application also produce the highest amount of elevation. In both forward and sideward elevation, the motion is checked by the tendon of the supraspinatus muscle and by contact of the greater tuberosity of the arm with the acromion. In backward elevation, the tension of the coracohumeral ligament checks further elevation. As the arm is swung from forward position through the lateral plane backward, one can see the different portions of the deltoid muscles contract in succession. When resistance is placed upon active elevation of the arm, a wider strip of muscle fibers can be brought into action at one time. Such arrangement will also bring out the supplementary action of the supraspinatus muscle which assists in raising the arm outward. The action of this muscle is very important for the deltoid, as it causes the head of the humerus to be held firmly against the glenoid fossa, and so counteracts that component of the deltoid which lifts the humeral head upward out of the glenoid fossa. While the trapezius muscle is not actively engaged in elevating the arm in the frontal plane before the angle of 90° abduction is reached,

still it is already in action as a stabilizer of the shoulder, preventing the downward pull of the shoulder-blade by the weight of the arm when the deltoid is contracted; therefore, action of the trapezius really starts long before the level of 90° is reached. This is important in cases of arthrodesis of the shoulder; in these instances one has to depend upon the action of the trapezius from the very first, when side motion of the arm begins. For this reason, the preparatory treatment of cases to be operated upon is as important as the postoperative development of this muscle.

Practical exercises to bring out motions of this type are the lifting of weights in the frontal plane, use of dumb-bells and chest weights.

Forward Raising of the Arm.—When the arm is raised forward, the anterior fibers of the deltoid contract, assisted during the first part of the arc of motion by the upper half of the pectoralis major. It will be noted, when the arm is placed in forward position, that there is also a rotation of the shoulder-blade around the side of the chest so that the glenoid fossa will look forward instead of outward as it does when the arm is elevated in lateral positiou. The shoulder-blade always follows closely the plane in which the arm is elevated. It is in the frontal plane in side elevation; it points diagonally outward and forward in forward elevation of the arm. The significance of this arrangement is apparent. The plane in which the shoulder-blade moves must always correspond to that of the arm in order to secure a free and unrestrained motion of the shoulder joint. In forward shifting of the shoulder-blade, the pectoralis minor is especially active. The forward swinging of the arm is therefore a good exercise for the pectoralis muscles, especially if held in abduction and against resistance in which case the pectoralis major also comes prominently into action.

Adduction of the Arm.—Adduction of the arm is carried out by the latissimus dorsi, pectoralis major, and teres major muscles. In the arc from 45° adduction to complete adduction, the scapula does not rotate; but from the horizontal to 45° adduction the scapula does rotate, if adduction motion is carried out against resistance, that is, against the contracture of the abductors. The shoulder-blade now rotates in a direction opposite to that seen in abduction of the arm. Strong resistance against adduction brings out the power of the pectoralis major, latissimus dorsi and teres major, and also of the scapular muscles, that is, rhomboids and levator anguli. Useful exercises in abduction and adduction motion are chest weights and the use of the vertical ladder. In backward extension of the arm, the back pull of the arm is accomplished by the lower three-fourths of the trapezius, while the back pull of the humerus against the scapula is carried out mainly by the infraspinatus and teres minor. Such muscles are admirably developed during the back stroke of rowing, by quarter circle exercises, Indian clubs, etc.

Rotatory Motion.—It now remains to consider the rotatory motions of the arms together with those of the scapula. Inward rotation of the

arm is accomplished by the subscapularis, teres major, latissimus dorsi, and pectoralis muscles. Inward rotation in any positioi of abducton will require a check upon the adductory tendencies of the latissimus dorsi and pectoralis major so that, in these positions, the action of deltoid and supraspinatus must be called upon. When developing substitutionary motion for lost pronation and supination, these rotatory motions in shoulder joint are of the greatest value. They can be taught and one can attain a great amount of skill and proficiency in inward and outward rotation of the whole extremity in the shoulder joint. A good method of exercising these motions are exercises forcing extreme rotation of forearm together with fixation of the shoulder-blade. If pronation and supination are checked, these rotatory motions of the shoulder joint will soon appear. The mechanical situation is then this: the humerus is held well balanced in a certain position of abduction by combined action of deltoid, pectoralis, and latissimus dorsi. Then the inward rotation is developed by exercises of the latissimus dorsi, pectoralis, teres major, and subscapularis; and the outward rotation by action of the infraspinatus and teres minor.

Massage and Passive Motion.—In massage of the shoulder, the patient is either in recumbent or in sitting position; if in the latter, the elbow is supported by the assistant and the massage of the deltoid is carried out with the arm in abduction to relax this muscle.

Passive abduction and outward rotation are especially indicated in extra-articular conditions leading to adduction and inward rotation contractures such as subdeltoid bursitis, birth-palsy, and contractures following prolonged fixation.

For afflictions of the joint and periarticular adhesions, friction and vibration are indicated. The shoulder joint can be reached easily by the finger in the pit of the axilla, especially if the arm is held in abduction. In the line of exercise treatment, timed motion with Indian clubs and wands are especially useful to carry out all circumductory motions. These may be supported by exercises with chest weights, especially those combined with a quarter circle in which the spine is given a position of hyperextension and in which especially the backward reach of the arms may be worked out.

Elbow—*The Triceps Muscle.*—The primary function of the triceps is the extension of the elbow joint, in which this muscle acts as a lever of the first order. It develops speed as well as power, both by virtue of the rather long leverage afforded to this muscle by the projection of the olecranon process and by virtue of the great number of short fibers which combine in the formation of power of this muscle. There are numerous practical ways in which this muscle may be developed (resistance exercises, parallel bars, trapeze exercises, ladder, etc.).

In the developing of this muscle, attention should be paid also to its function as a stabilizer of the shoulder joint. This stabilization is carried out by the long head of the triceps, which holds the humerus

against the glenoid fossa, and this is, in fact, the main function of this part of the muscle, according to Duchenne. In all cases of paralysis of the abductors, the stabilization of the head of the humerus becomes of great importance because it is the only factor which counteracts the pull of gravity tending to distract the head from its bed in the glenoid fossa. In the absence of the abductors of the shoulder, the triceps, supported by the biceps and coracobrachialis, protects the joint from a position of downward subluxation or dislocation. All forcible motion, carried out either in the shoulder, elbow, or wrist joints, calls for firm stabilization in the scapulohumeral joint. For this reason, the triceps plays an active part in almost all of the forcible motions of the upper extremity, such as throwing, lifting, grasping, and other motions of the forearms and hand as well.

Biceps.—The biceps can be developed in a similar way by simple exercises on the horizontal and parallel bars and by gymnastic exercises with dumb-bells, Indian clubs, and wands. Development of the biceps also aids in stabilization of the shoulder joint.

If one wishes to develop the supinatory power of the biceps, the elbow should be in a position of semiflexion of about 120° to 135°. At a more acute angle, the muscle is too much relaxed to fully display its supinatory power. In an extended position, on the other hand, while the tension of the muscle is considerable, its angle of application becomes comparatively small and this mechanical disadvantage diminishes its supinatory power. It has been mentioned that in this position the supinator brevis has to come to the aid of the biceps in the act of supination. It is easy to find movements in practical life which will serve the purpose of developing these muscles, and it is unnecessary to dwell upon a long list of suggestions

Pronation of the Elbow.—The position of choice in starting development of pronation is slight flexion of the elbow and hyperextension of the wrist. In this position of the elbow, the round pronator works at a favorable angle and in its action is readily supported by the pronator quadratus. The hyperextension of the wrist gives opportunity to the secondary pronators to come to action, especially the flexor carpi radialis. Pronation and supination movements should be carried out alternately in flexion and extension because of the fact that different muscle action becomes prevalent in one or the other of these positions. Active pronatory and supinatory exercises can be carried out with advantage by dumb-bells and wands. They should be carried out both with and without resistance.

Massage.—The elbow joint is easily accessible to direct massage, especially in its lateral and posterior aspects. The elbow is held in flexion with the forearm resting upon the table and the patient in sitting position. Friction and vibratory movements can be readily applied to either the lateral or posterior aspects of the joint or in front, at the inner or outer bicipital groove.

Passive motion is of special importance in periarticular adhesions

in front of the elbow joint, such as is seen after prolonged fixation, or following fractures, or in Volkmann's contractures, or in contractures of congenital nature. Club swinging, hanging, and carrying weights is a valuable support for the mechanical treatment.

The Elementary Motions of the Hand.—The gripping power of the hand should be developed in hyperextension of the wrist. The use of a tool requiring a grip of some force, such as a screw driver, represents an easy and practical application. In the development of circumductory motions of the hand, Indian clubs or moderately weighted iron dumb-bells are useful, care being taken that the forearm be properly immobilized. The writer is using to advantage a so-called wrist roll; a roll of varying diameter which in turning lifts a weight, and in the turning of which, according to the diameter chosen, more or less gripping power is required (Plate XLVII, 8).

Massage.—Massage of the forearm muscles is carried out best with the patient in sitting position and the arm resting upon a board. The different muscle groups of the forearm, as well as those of the thenar and hypothenar eminence, are taken up separately in the application of effleurage and pétrissage. Friction, massage, and vibration are excellent means for mobilization of the wrist and finger joints.

In carrying out passive stretching of the wrist joint, the hand of the operator grips that of the patient from below, gently forcing the palm in a dorsal direction. In this position, circumductory motion can be carried out also.

In the treatment of flexion deformity of the fingers by passive motion, not only each finger but each finger joint must be taken up separately. When the result of this treatment is to be maintained by splinting the splint should also have individual finger parts pliable enough to give each joint the proper position.

Technic of the Medicomechanical Development of Substitutionary Motion, Following Operations—*Arthrodesis of the Shoulder.*—In cases of arthrodesis of the shoulder, the postoperative development of the trapezius muscle becomes an important factor. It can be carried out by active exercises, with or without resistance, elevating the arm and shoulder by contraction of trapezius muscle. The first attempts at motion should be carried out in the recumbent position, so that no gravital strain may interfere with the action of the muscle. When this is accomplished to a degree where the muscle is able to hold the entire extremity in abduction without too great an effort, exercises in upright position are added. It must be kept in mind that the forcible contraction of the trapezius muscle is very prone to produce inclination of the head to its side. Postural exercises must then be provided for, which will secure a symmetrical position of the head. This is best done by developing the action of the trapezius and other shoulder muscles of the other side.

Development of Pronators of the Forearm and Flexors of the Wrist into Flexors of the Elbow.—Necessity for this arises in cases where a

LEGEND FOR PLATE XLVII

PHYSIOTHERAPY

Fig. 1.—Mobilization of Elbow.

Fig. 2.—Mobilization and Massage of Shoulder.

Fig. 3.—Abduction Exercises of Shoulder.

Fig. 4.—Massage of Hand.

Fig. 5.—Dumb-bell Exercises for Shoulder.

Fig. 6.—Extension Exercises for Shoulder.

Fig. 7.—Pronation and Supination Exercises.

Fig. 8.—Exercises for Forearm and Finger Flexors (Wrist Roll).

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muscle transposition has been carried out on the forearm flexors. In this operation, the flexors of the wrist are assuming the rôle of the lost biceps and brachialis anticus, for which they are better fitted after their point of origin has been transposed to a higher level at the humerus. It requires a great deal of careful after treatment to develop this substitutionary motion to a point where it becomes of real practical value. The first condition is that all attempts of flexion of the elbow must be carried out in the horizontal position, so that the antagonistic force of gravity is eliminated. The starting point is one of flexion in the elbow at less than right angle, so as to avoid overextension of the flexor muscles. The wrist is held in slight hyperextension to give the proper amount of tension and the exercises are given carefully in several daily sittings, each one covering only a very short period of time. During all the exercises, one must be on constant guard against undue stretching of the muscles by unsuitable positions of the elbow, and against exhaustion of these muscles by unduly prolonged sittings of muscular exercises.

Development of Substitutionary Pronation and Supination.—Situations may arise in which active or passive pronation and supination is impossible, either by reason of contractures or synostoses of the forearm bone, or by reason of paralytic conditions. Rotation can be developed in these cases in the shoulder joint and it will, to a large measure, take the place of pronation and supination movement. The muscle mechanics underlying this method have already been explained at length. By means of supination exercises, such as used in the development of the physiological supination, this substitutionary supination will be developed also. Wand exercises, dumb-bells, and the use of certain tools, screw drivers, turning of door knobs, etc., are simple and effective means for this purpose (Plate XLVII).

Records.—The keeping of records in the course of medicomechanical treatment is an essential factor in judging the results obtained. Graphic records should be made and carefully kept. They should show not only the deformity of the joint prevailing at the time the treatment is begun, but must also demonstrate graphically, from measurements taken at regular intervals, the improvement obtained by treatment. Considerable thought and attention has been given to the standardization of joint records and it was found to be a rather difficult matter, if both accuracy and simplicity of records are to be combined. In a hinged joint, the matter is rather simple because the results can be charted readily upon a planimetrical record based upon the two-coördinate system. But in the tridimensional motions of the shoulder or of the wrist, the matter becomes considerably complicated. An elaborate apparatus is the so-called joint perimeter, devised by Huebscher; another is the globe net perimeter of Quervain and Ludloff. Other perimeters are the globe magnet perimeter, and the so-called swimmer globe perimeter, consisting of a globe filled with oil and carrying a swimmer on top. The latter again is supplied with a compass needle

so that declinations can be read in all three dimensions. In the so-called joint perigraph, a double hollow sphere is used, the inner one rotating freely in the outer, with a pencil fastened to the inner globe graphing the movement upon the paper which lines the hollow outer globe. One may also mention the projection joint perigraph, in which a mercury drop moves freely in a hollow globe studded with the ends of fine copper wire arranged in parallels and meridians at even distances. These copper wires transmit electric impulses as the current is closed over the wire ends by contact with the mercury drop. In the ordinary course of mechanotherapeutic treatment, such complicated apparatus are hardly necessary and one will be well able to get along with simple devices. Nutter records finger deformities by the tracing method, and simple graphic finger curves obtained by tracing are also used by Gottlieb. Such an arrangement is entirely sufficient for ordinary use and it is only necessary to agree upon certain starting positions from which the angulation of a joint is measured. For instance, in the elbow, 180° should mean full extension; in the shoulder 180°, full abduction to the perpendicular. In pronation and supination, the starting or neutral position is the so-called thumb-up position, from which the degrees of pronation and supination are measured in either direction. The writer has used the simple graphic curves based upon the Cartesian coördinate system for the measurement of movements of the fingers and elbow joints. In the elbow joint for instance, the ordinata means the degrees of flexion and extension obtained, the base line being that of right angular flexion. Above, it is flexion up to full flexion and, below, extension up to full extension. The abscissa means the element of time in which the change in range of motion is obtained in units of days, weeks, months, etc. In the wrist and shoulder joint, the amphiarthrotic motions can be analyzed in two planes. For instance, in the shoulder: abduction and adduction, flexion and extension. Abduction and adduction is marked on the ordinata, and flexion and extension on the abscissa. In this way, the range of motion is signified by a quadrangular figure similar to the periscopic measurement of the field of vision. In this instance, in and outward rotation has to be recorded separately. In the wrist joint, the two-coördinate system serves for the recording of flexion and extension in the ordinata, and abduction and adduction in the abscissa, of the system.

MUSCLE EDUCATION AND OCCUPATIONAL THERAPY [1]

Muscle Education.—This is based upon the analysis of everyday motion into its physiological elements, thereby arriving at elementary motions which are simple and yet serve an intelligent purpose. It links up closely with the medicomechanical treatment in that it takes over

[1] With the coöperation of Miss M. Prosser, in charge of the work of muscle education and occupational Therapy.

the elementary motion developed by physiological methods and makes it subservient to the will and purpose of the patient. It is connected on the other side with occupational therapy by furnishing, as it were, the building stones upon which the edifice of the more complicated motions, underlying crafts, and accomplishments, is erected.

Occupational Therapy.—This is based upon the principle that the best type of remedial exercises is that which calls into play a series of specified voluntary movements involved in the ordinary trades and occupations in life (Baldwin).

Muscle education is based upon the principle that in order to attain the degree whereby such specified voluntary motions will be obtained, an intermediate stage must be passed through, in which the elementary motions developed by mechanotherapy are made subservient, not only to will and purpose, but especially, also, to coördination and to the element of time. The fundamental reason for the necessity of muscle education as an intermediate step between mechanotherapy and occupational therapy in the ordinary sense is, then, the fact that it serves as a link bridging physiological motion and handcraft. The fundamental reason why attempts at developing occupational therapy often fail in given cases is because the complicated motion involved will be beyond the patient's ability to time and to coördinate them, unless their elementary constituents have first been developed in subserviency to coördination and time.

In the development of muscle education, the writer has been careful to base the whole system upon four fundamental conditions:

1. A clear recognition of what the elementary motions are in the different joints of the extremity (standardization of motions).
2. A uniformity of the working tools and instruments; and of the choice of practical objects to be used in developing such elementary motions (standardization of work).
3. A system of developing elementary motion based upon the close relationship of the elementary act of motion to the unit of time. In other words, the methods and progress are judged as a product of both time and motion (coördination of movement and time).
4. An accurate system of records by which progress can be measured with a degree of accuracy and reliability compatible with an easy application (standardization of records, based upon principles 1-3).

Technic of Muscle Educational Treatment—*Shoulder.*—Elevation exercises of the shoulder on the blackboard.

a. Push and pull exercise (up and down strokes).
b. Continuous oval exercise (progressive circling).
c. Compact oval exercise (shading of ovals by up and down stroke; combinations a and b).

These exercises are timed, the elementary movements being done either upon count or at certain rate per minute. The exercises combine

both the elevation of the shoulder and flexion and extension movement of the elbow.

Exercises for the Hand—Cube and Peg Drill.—The Cube and Peg Drill consists in the gripping of cubes of special size and placing them one upon top of the other at a certain rate per minute. These exercises involve the following elementary motions: the closing of the fingers, the release of the fingers, opposition of the thumb, slight pronation and supination motion.

To a lesser degree: flexion and extension in the elbow, elevation of the shoulder.

The following material is used for the exercises: 2 inch cubes; 1 inch cubes; ½ inch cubes; ¼ inch pegs and ⅛ inch pegs. The latter are inserted into peg holes arranged in the manner of a cribbage board (Plate XLVIII, 1-4).

Records.—In order to keep accurate records, it is necessary first of all to have a standard by which the functional ability of the hand or arm can be measured. One may have the choice of developing either an absolute or a relative standard upon which to base the records. An absolute standard for a given occupation, such as the setting of cubes or pegs, could be obtained, only by ascertaining the normal values for similar occupations, from examinations of a large number of patients of the same age. But it is a matter of great difficulty to arrive at an absolute standard, not only because of the long series of tests on different groups of normal individuals, but also because there are other variables entering into the calculations, which make the results of tests rather inaccurate. One of these sources of error may be the mental attitude of the patient at the time the test is given; another, his natural dexterity; his state of concentration, etc. Therefore, when confronted with this task, we found it nearly impossible to establish absolute standards of accuracy which would be of binding value in comparing therapeutic results.

The relative standard means the comparison of the afflicted extremity with the normal. It may not be as accurate or scientific as the absolute standard, but it excludes largely the sources of error, caused by variation of concentration and mental attitude, for instance, or by differences in individual dexterity, etc. For the ordinary routine work, it has proved adequate and the tables given are all based upon this method of comparison.

The second point of importance is the advisability of reducing the curves obtained to a percentage basis. By this is meant that, the working capacity of the normal extremity being 100, the work of the afflicted extremity is compared in terms of percentage and is so expressed by a graph. The following examples of graphic records on patients made will give a conception of the manner in which the system of percentage records has been carried out. The total of patients with disabilities of the upper extremity, treated in the last two years by muscle educational methods, were 97, distributed as follows:

LEGEND FOR PLATE XLVIII

MUSCLE EDUCATION

FIG. 1.—EQUIPMENT FOR CUBE AND PEG DRILL (2″, 1″, ½″ CUBES, ¼″ AND ⅛″ PEGS).

FIG. 2.—EXERCISES WITH 2-INCH CUBES.

FIG. 3.—PEG EXERCISES.

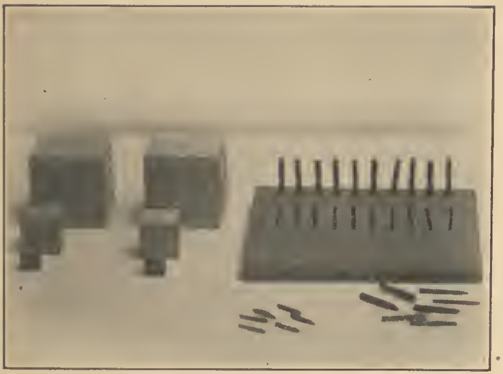
FIG. 4.—ARM-RAISING EXERCISES: PUSH AND PULL, ASCENDING OVAL, HORIZONTAL OVAL, COMPACT OVAL.

FIG. 5.—JIG SAW AND FILE.

FIG. 6.—DRILL, AWL, PLANE AND FILE.

FIG. 7.—WEAVING, BASKETRY AND CANING.

FIG. 8.—CLASS IN OCCUPATIONAL THERAPY.



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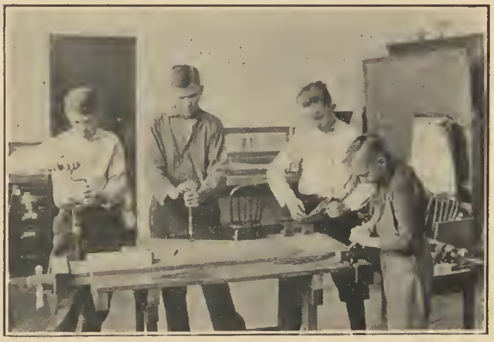

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	Cases
Infantile paralysis	36
Spastic paralysis	27
Fracture deformities	5
Arthritis of the upper extremity	6
Birth-palsies	4
Congenital fractures and deformities	6
Volkmann's contractures	2
Inflammatory and cicatricial contractures	6
Traumatic paralysis	5
Total	97

Case Reports.—T. G., infantile paralysis. Flail shoulder. Operative treatment: arthrodesis of the shoulder. The curves express the percentage of arm reach in elevation of the arm with the elbow extended and the progress of this reach after different numbers of trials. As a rule, not more than 1 or 2 trials are made a day, because the patient easily becomes tired and exhausted and loses interest in the work. The graphic curve in this case shows that the range had increased from 41.6 per cent to 72.3 per cent, or from 12½ inches of elevation to 21 inches in ordinary push and pull exercises.

In the rhythmic drill of the compact oval, this progress was from 44 to 69 per cent or from 12⅜ to 20⅛ inches of eleveation; and, in the ascending oval, the progress was from 22 to 68 per cent. In full extension exercises on the wall, the percentage increased from 21 per cent to 78 per cent. The starting point of the shoulder exercises is given by the condition of the patient after the cast had been removed following arthrodesis, and after a sufficient time of medicomechanical treatment had been allowed for free elevation of the arm up to about the horizontal. The full reach of the upper extremity in vertical abduction is taken as the base line or 100 per cent (Plate XLIX, 1-4).

H. S., paralysis of the fingers and thumb following severe burn injury from live wire destroying the tendons at the wrist. Percentage record: Cube and Peg Drill. With the 2-inch cubes, the normal left hand reached frequency of 120 to 160 per minute; the defective right hand 72 to 132 per minute, the percentage progressing then from 60 per cent to 94 per cent. With the 1-inch cubes, the percentage of the defective hand progressed from 61 per cent to 93 per cent. With the ½-inch cubes, the percentage progressed from 58 to 92 per cent. In using the ¼-inch cubes, no work could be done until the 4th trial, from which time on, the efficiency improved from 0 to 40 per cent. With the ⅛-inch peg, no work was possible until the 14th trial. From this time on, the efficiency improved from 0 to 43 per cent (Plate XLIX, 5, 6; L, 1, 2, 3).

O. K., 15 years. Volkmann's contracture. Preceding operative treatment: plastic lengthening of the tendons.

Percentage curve: 1 inch cubes: range of percentage increased from 78.6 to 98.8 per cent; with the ¼ inch pegs from 28 to 50 per cent (Plate L, 4, 5).

F. N., 35 years. Live wire burn of both wrists. Preceding operation: tenoplasty and flexor plasties of the thumbs. The progress of the work done by the thumb and index finger with 2 inch cubes, 1 inch cubes, and ½ inch cubes, is seen in the accompanying chart. The absolute efficiency reaching 105 to 110 movements in the 2 inch, 105 in the 1 inch, and 75 in the ½ inch cube. In the use of the thumb and middle finger, the accompanying curve shows that the dexterity of this movement increased from 7 movements at the first trial to 80 at the last (Plate L, 6, 7).

A study of these charts will reveal several factors which otherwise would not be so distinctly apparent. In the first place, one may learn exactly where function is bound by physiological limits. It may be, for instance, that in a case no difficulty of handling objects is seen in the percentage curve and that the lines go steadily up in the graphs. Then an object is reached, ¼ inch peg for instance, where no amount of drill will produce progress and the percentage curve remains persistently low. At this point, then, we have an insurmountable obstacle, from the muscle educational point at least, and it may or may not be possible to overcome it by operation. In many cases this leads to distinct operative indications. For instance, the approximation of thumb and index finger, or of thumb and middle finger, may prove sufficient up to a certain point, whereas no amount of further exercise and practice will bring about material improvement. It is then necessary to consider whether the obstacle can be removed by operative procedure. In a number of instances, it could. For example, in cases of deficient opposition of the thumb, an additional thumb plasty subsequently raises the efficiency, so that all simple objects can be handled with comparative ease. In this fashion, many operative indications grew out of the progress of the muscle educational treatment and continuous contact between the surgeon and the teacher was necessary in order to appraise the possibilities of reconstruction. In the cases in which the smaller objects, such as ¼ and ⅛ inch pegs, were handled with fair percentage (50 per cent or over), the patient was usually deemed capable of entering into occupational instruction, since 50 per cent efficiency in ½ inch cubes enables the patient to run scroll saw, drill, and larger tools in general.

The timed exercises, we believe, have proved of greatest value in this work. They stimulate the patient in his effort and are an incentive to him to beat his own records with each subsequent trial. They are a great factor in forcing an issue with the will and coördination power of the patient. As far as possible, the patients are encouraged to keep their own records.

In establishing this system of muscle education, stress was laid especially upon the simplicity of the objects to be used for the training. The

LEGEND FOR PLATE XLIX

1. Arm-raising Rhythmic Drill.
   Percentage of Defective Right Arm.

2. Arm-raising Rhythmic Drill.
   Push-and-pull Exercise.
   Range of Defective Right Arm.

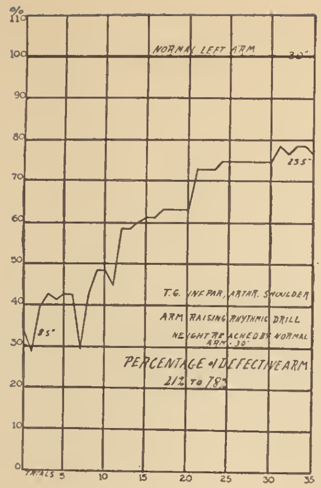
3. Arm-raising Rhythmic Drill.
   Ascending Oval.
   Range of Defective Right Arm.

4. Arm-raising Rhythmic Drill.
   Compact Oval.
   Range of Defective Arm.

5. Cube and Peg Drill (Two Inch Cubes).
   Percentage Improvement of Defective Right Hand.

6. Cube and Peg Drill (One Inch Cubes).
   Percentage Improvement of Defective Right Hand.

PLATE XLIX



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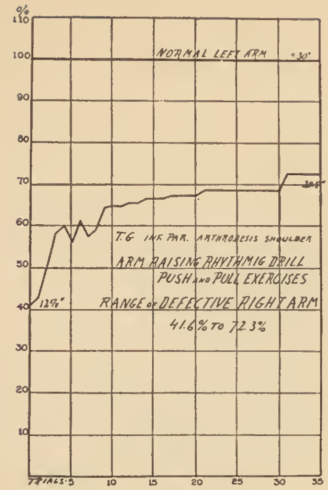

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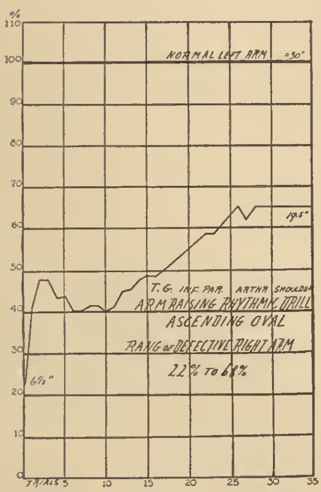

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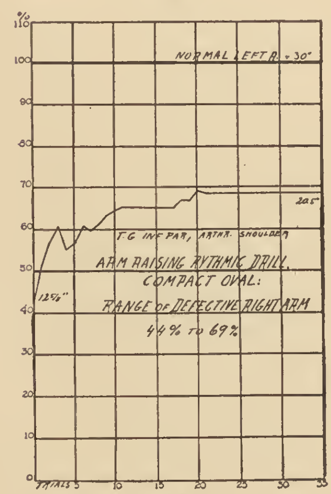

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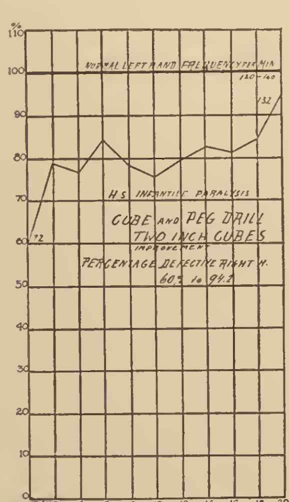

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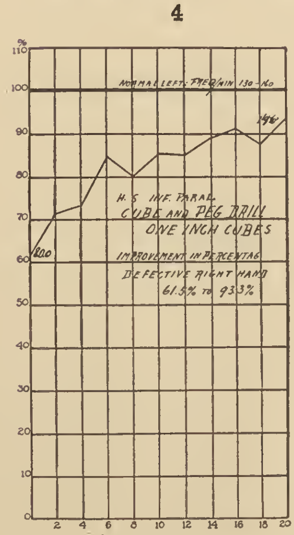


6

LEGEND FOR PLATE L

1. Cube and Peg Drill (Half Inch Cubes).
   Percentage Improvement of Defective Right Hand.

2. Cube and Peg Drill (Quarter Inch Pegs).
   Percentage Improvement of Defective Right Hand.

3. Cube and Peg Drill (Eighth Inch Pegs).
   Percentage Improvement of Defective Right Hand.

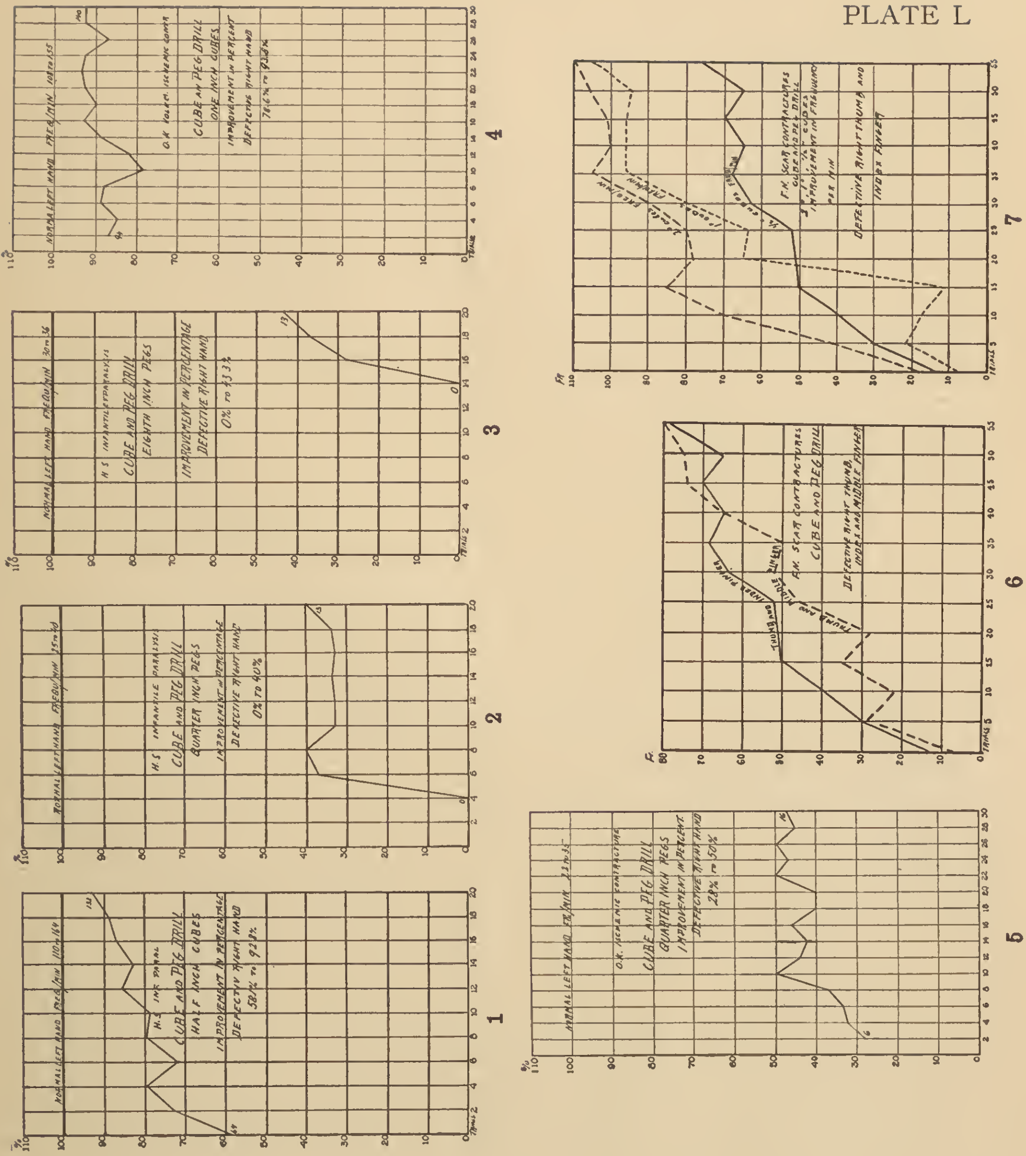
4. Cube and Peg Drill (One Inch Cubes).
   Percentage Improvement of Defective Right Hand.

5. Cube and Peg Drill (Quarter Inch Pegs).
   Percentage Improvement of Defective Right Hand.

6. Cube and Peg Drill.
   Defective Right Thumb, Index and Middle Fingers.
   Improvement in Frequency per Minute.

7. Cube and Peg Drill (Two Inch, One Inch and Half Inch Cubes).
   Defective Right Thumb, Index and Middle Fingers.
   Improvement in Frequency per Minute.

PLATE L


1
NORMAL LEFT HAND FREQ/MIN 110 TO 164
H.S. INF. PARAL.
CUBE AND PEG DRILL
HALF INCH CUBES
IMPROVEMENT IN PERCENTAGE
DEFECTIVE RIGHT HAND
58% TO 92.8%
2
NORMAL LEFT HAND FREQU/MIN 75 TO 40
H.S. INFANTILE PARALYSIS
CUBE AND PEG DRILL
QUARTER INCH PEGS
IMPROVEMENT IN PERCENTAGE
DEFECTIVE RIGHT HAND
0% TO 40%
3
NORMAL LEFT HAND FREQU/MIN 30 TO 36
H.S. INFANTILE PARALYSIS
CUBE AND PEG DRILL
EIGHTH INCH PEGS
IMPROVEMENT IN PERCENTAGE
DEFECTIVE RIGHT HAND
4
NORMAL LEFT HAND FREQ/MIN 108 TO 155
CUBE AND PEG DRILL
ONE INCH CUBES
IMPROVEMENT IN PERCENT
DEFECTIVE RIGHT HAND
5
O.K. ISCHEMIC CONTRACTURE
CUBE AND PEG DRILL
QUARTER INCH PEGS
IMPROVEMENT IN PERCENT
DEFECTIVE RIGHT HAND
28% TO 50%
6
F.M. SCAR CONTRACTURES
CUBE AND PEG DRILL
DEFECTIVE RIGHT THUMB, INDEX AND MIDDLE FINGER
7
F.K. SCAR CONTRACTURES
CUBE AND PEG DRILL
IMPROVEMENT IN FREQUENCY PER MIN
DEFECTIVE RIGHT THUMB AND INDEX FINGER

cube and pegs are obtainable everywhere and they do not entail any great expense. No expensive apparatus is used. Older patients soon learn the technic of this simple drill and attain a certain proficiency in making records; they also require less supervision as time goes on. How far this type of muscle educational drill will go toward perfecting the efficiency of the hand, the writer is not able to say, but there seems to be no doubt of the fact that his sysem of elementary muscle drill by means of timed exercises with standardized and simple objects fills in a breach between the physiotherapy and the occupational therapy proper, and will enable many a patient to enter the field of vocational training.

Occupational Therapy.—Occupational exercises, in the stricter sense, are started when the patient attains a certain degree of proficiency in the timed muscle educational drill.

In general, one may estimate that a 50 per cent efficiency in ½ inch cubes qualifies the hand for the handling of larger tools, such as drill handle, screw driver, saw or plane; the same efficiency in ¼ inch cubes or ⅛ inch pegs qualifies it for caning, reedwork, etc.

Molding in clay is used as the first step, as it is an excellent means to develop the strength of fingers and thumb.

Crafts Presented and Material Used

Modeling.—Plasticine, wax, papier-mâché, plasterwork, cement work, pottery.

Weaving.—Hand and cardboard loom weaving, beadwork, simple rug and mort weaving.

Basketry.—Pine needle, raffia, reedwork, chair caning.

Woodwork.—Simple bench work and toy making; use and care of tools; scroll saw.

Wood Carving.—Whittling, chip carving, use of knives, chisels, gauges.

Bookbinding.—Cardboard and paper construction.

Metal Work.—Copper, brass, tin.

Leather Work.—Flat modeling, embossing, lacing, cutwork, stenciling and dyeing of leather.

Sewing and Textiles.—Simple stitching, embroidery, cross-stitching, appliqué work, crochet knitting, cord knitting, rake and spool knitting; braided and hooked rug making.

Design and Color.—Principles introduced and applied to subjects taught.

In most cases, muscle educational drill and occupational instruction run parallel; the patient, as he masters the various steps of the drill, takes up more and more of the occupational work also, in the measure in which his physical ability improves.

This breaks the monotony of drill work and gives the patients new incentive and interest. One period of drill and one (longer) period of occupational work is given daily.

The occupational work is carried out mainly in groups, under the supervision of the teachers; in many cases, however, individual and bedside work must be given. Not only for the sake of physical improvement, but also in the interest of the mental attitude of the patient, bedside instruction is carried out as early and as extensively as conditions will permit.

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